Elements of Electrical Technology

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Instructional-cum-Practical Manual
for
Repair, Maintenance and Rewinding of Electrical Motors

Class XI

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राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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FOREWORD

The programme of vocationalization of higher secondary education has been accepted by the country as it holds forth great promise for linking education with the productivity and economic development of the country.

In view of the importance of the programme, the National Council of Educational Research and Training (NCERT) is making an all-out effort to provide academic support to the implementing agencies in the States. One of the major contributions of the NCERT is in the field of curriculum development and in the development of model instructional materials The materials are developed through workshops in which experts, subject specialists, employees' representatives, curriculum framers and teachers of vocational courses are involved.

The present manual 'Elements of Electrical Technology' has been developed for the students studying Repair, Maintenance and Rewinding of Electrical Motors (Class XI) and allied vocations. It is being published for wider dissemination amongst students and teachers throughout the country. I hope that they will find the manual useful.

I am grateful to all those who have contributed to the development of this manual. I must acknowledge the role played by Professor A. K Mishra, Project Director, Pandit Sunderlal Sharma Central Institute of Vocational Education, in inspiring his colleagues in their endeavour to develop this instructional material. Shri S. Ray, Senior Lecturer who functioned as the Project Coordinator for developing this title, deserves special mention for the efforts he put in to bring out this publication.

We would welcome suggestions for improvement of this manual.

A. K. SHARMA
Director
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PREFACE

Ever since the introduction of vocationalization in our school system by several States and Union Territories, it has been felt that the paucity of appropriate instructional materials has been felt as one of the major constraints in the implementation of the programme and also a source of great hardship to pupils offering vocational studies at the higher secondary stage.

To overcome this shortcoming, the erstwhile Department of Vocationalization of Education of the National Council of Educational Research and Training (NCERT) started a modest programme of developing instructional materials of diverse types to fill up this void in all the major areas of vocational education The task is too gigantic to be completed by any single agency but the model materials being developed by us might provide guidance and impetus to the authors and agencies desiring to contribute in this area. These are based on the national guidelines developed by a working group of experts constituted by the NCERT.

The present manual is on Elements of Electrical Technology and is meant for the pupils and teachers teaching Repair, Maintenance and Rewinding of Electrical Motors (Class XI) and allied vocations being offered in a number of States It contains instructions to perform certain activities (Practical Exercises) with simple steps to follow, precautions to be taken and data to be recorded and processed by the pupils. Each activity is complete with objective, relevant information, procedure, evaluation,etc It is hoped that the users will find them directly useful.

The experimental edition of the manual was developed by a group of experts in a workshop held at the Institute of Engineering and Rural Technology, Allahabad. It was reviewed and revised through a committee of experts in the same workshop.

The names of the contributors and reviewers are mentioned elsewhere and their contribution is acknowledged with admiration. Shri S. Ray, Co-ordinator of this project, deserves special thanks for editing, reviewing and giving the manual its present form. The assistance given by everyone in the Institute of Engineering and Rural Technology, Allahabad and the erstwhile Department of Vocationalization of Education, NCERT is also thankfully acknowledged.

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GANDHIJI'S TALISMAN

"I will give you a talisman. Whenever you are in doubt or when the self becomes too much with you, apply the following test :

Recall the face of the poorest and the weakest man whom you may have seen and ask yourself if the step you contemplate is going to be of any use to him. Will he gain anything by it ? Will it restore him to a control over his own life and destiny ? In other words, will it lead to Swaraj for the hungry and spiritually starving millions ?

Then you will find your doubts and your self melting away."

mkGandhi

ABOUT THE MANUAL

So far about fifty different vocational courses in engineering and technology have been introduced by seventeen States and four Union Territories under the programme of Vocationalization of Education. These courses are being pursued for the last thirteen or fourteen years. Right from their inception, the erstwhlile Department of Vocationalization of Education in the NCERT had been working hand in hand with the concerned State organisations, through various programmes especially organised for the State officials, vocational teachers and others In fact all through this period the Department conducted on-the-spot studies of the vocational programme in a large number of States to find out the merits and demerits of the programme and was able to suggest appropriate measures to resolve many problems that confronted the "engineering and technical vocational education". These programmes revealed a great dearth of suitable instructional materials and the need for practical manuals, the lack of which was especially and urgently felt. In this context the development of instructional materials and imparting practical training assumed even greater importance especially when one considered the purpose for which the vocationalization of education had been launched. The main aim of the programme was to prepare the pupils for purposeful and gainful employment (wage-employment or self-employment)

The Department constituted a Working Group in 1982 to formulate guidelines to work out models on a variety of instructional materials Based on the guidelines formulated by the Working Group, Repair, Maintenance and Rewinding of Electrical Motors was selected by the Department for the purpose of developing of the instructional materials in a phased manner. To begin with, the development of instructional-cum-practical manuals was taken up.

The content of the 'Repair, Maintenance and Rewinding of Electrical Motors' course was thoroughly analysed after which it was felt that six manuals would be necessary to cater to the needs of those taking up this course. The present manual, Elements of Electrical Technology, is one of them This manual is meant to help both teachers and pupils. Each activity is complete with specific objectives, related information, equipment and materials, procedure, observations, precautions and questions for evaluation. In order to acquaint the pupils with each activity, the teacher is expected to provide them with the required theoretical knowledge or information related to it. This will help the pupils in acquiring proper understanding of the activity and enable them to perform it properly and effectively

In order to meet the stipulated objectives, the activities include the study and manipulation of tools and instruments which a mechanic of electric motor would be required to use in his professional career.

The evaluation of the activities performed by the pupils shall be based on specific objectives. The teacher shall evaluate all the aspects which are relevant to achieve the specific objectives. This will contribute in inducing the 'expected behavioural outcome'. Evaluation is an important aspect of performing the activities. Each activity should be assessed through evaluation based on knowledge, acquired skills and competencies, attitude and aptitude towards work, activity performance, application, maintenance of record concerned with activity.

Tabular representation of the suggested evaluation scheme is as follows:

Sl. No	*Components*	*Marks allotted*	*Marks awarded*
(i)	Knowledge	20	
(ii)	Acquired skills and competencies	35	
(iii)	Attitude and aptitude towards work	15	
(iv)	Activity performance	10	
(v)	Application	10	
(vi)	Maintenance of activity record	10	
	Total marks	100	

At the end of each activity, some questions for evaluation are given. The pupils shall answer these questions on the completion of each activity and teacher shall examine them. If required, necessary corrections and suitable suggestions should be incorporated by the teacher. However, the answers to these questions should not be considered for the purpose of awarding final mark or grade.

CONTENTS

FOREWORD v
PREFACE vii
ACKNOWLEDGEMENTS ix
ABOUT THE MANUAL xi

Activities

1. To Measure Conductor Resistance by Drop Test Method 1
2 To Measure Equivalent Resistance of a Series Circuit 3
3 To Measure Equivalent Resistance of a Parallel Circuit 5
4. To Study the Effect of Temperature on Resistance in a Tungsten-Filament Lamp 7
5. To Study the Effect of Temperature on Resistance in a Carbon-Filament Lamp 9
6. To Study the Types of Fuses 11
7. To Study the Fusing Characteristic of Different Types of Fuses 13
8. To Measure the Insulation Resistance and Continuity of a Test Cable by a Megger 15
9. To Verify Kirchhoff's Law 18
10. To Measure the Unknown Resistance by the Wheatstone's Bridge 21
11. To Study the Phenomenon of Battery Charging 24
12 To Make an Electromagnet and Study the Direction of Current/Polarity 29
13. To Study a Magnetic Circuit 31
14. To Study the Principle of Mutual Inductance 33
15. To Study the Phase Relationship of Voltage and Current in a Circuit Containing Resistance 35

16. To Study the Phase Relationship of Voltage and Current in a Circuit Containing Resistance and Inductance in Series 37

17. To Study the Phase Relationship in an A C. Parallel Circuit Containing Resistance and Inductance 39

18 To Study the Voltage and Current Relationship in an A C. Parallel Circuit Containing Resistance and Capacitance 41

19. To Study the Charging and Discharging of a Capacitor 43

20. To Study the Relationship between Phase Voltage and Line Voltage and Phase Current and Line Current in a Three Phase Star/Delta Connection 46

21. To Measure Power in a Three-Phase-Star/Delta Connected Balanced Lamp Load 50

22 To Study the Use of Moving Coil Instruments (Ammeter and Voltmeter) 52

23 To Study the Moving Iron Instruments (Ammeter and Voltmeter) 54

24. To Measure Power in a Single-Phase Circuit by Wattmeter 56

25. To Measure Energy in a Single-Phase Circuit by Energy Meter 59

26. To Caliberate a Single-Phase Energy Meter with the Help of a Substandard Energy Meter 61

27. To Measure Earth Resistance by an Earth Tester 64

28 To Study a Multimeter and Its Uses 66

29 To Measure Transformation Ratio of a Single-Phase Transformer 68

30. To Determine the Efficiency of a Single-Phase Transformer 70

31. To Measure Current in an A C. Circuit using Current Transformer and Tong Tester 72

32. A Visit to a Hydroelectric Power Station 75

33. A Visit to a Thermal Power Station 78

34 A Visit to a Substation 80

35. A Visit to an Industry 83

APPENDIX 85

ACTIVITY NO 1

To Measure Conductor Resistance by Drop Test Method

Specific Objectives

(i) To measure the resistance drop in a given circuit with the help of a voltmeter and an ammeter

(ii) To verify that the flow of current varies inversally to resistance in an electrical circuit at a constant temperature.

Related Information

Resistance opposes (slows down) the flow of current Different materials offer different resistances.

As per Ohm's law the current in a given circuit is directly proportional to the applied voltage and inversally proportional to the resistance, temperature being constant. This is illustrated by the following equations .

$$I = \frac{V}{R} \quad ..(1)$$

$$R = \frac{V}{I} \quad .(2)$$

$$V = IR \quad .(3)$$

Where

R = resistance in the circuit

V = voltage across the resistance

I = current flowing through the resistance

The resistance is measured in Ohms. The resistance measured at room temperature is known as cold resistance.

Equipment and Materials

(i) A piece of copper/aluminium wire — 1 meter

(ii) Battery 6 — Volts (V) — 1

(iii) Ammeter DC 0-10 Amperes (A) — 1

(iv) Voltmeter DC 0-10v — 1

(v) Rheostat 10 ohms, 5A — 1 (variables)

(vi) Electrician knife — 1

Procedure

(i) Connect the ammeter voltmeter, rheostat and wire as shown in Fig 1 1

(ii) Close the switch (Sw) and keep the rheostat at maximum so that a small current flows through the circuit.

(iii) Note the ammeter and voltmeter readings.

(iv) Change the current by adjusting the rheostat and note the readings.

(v) Repeat the step no (iv) several times and record the readings of the voltmeter and ammeter

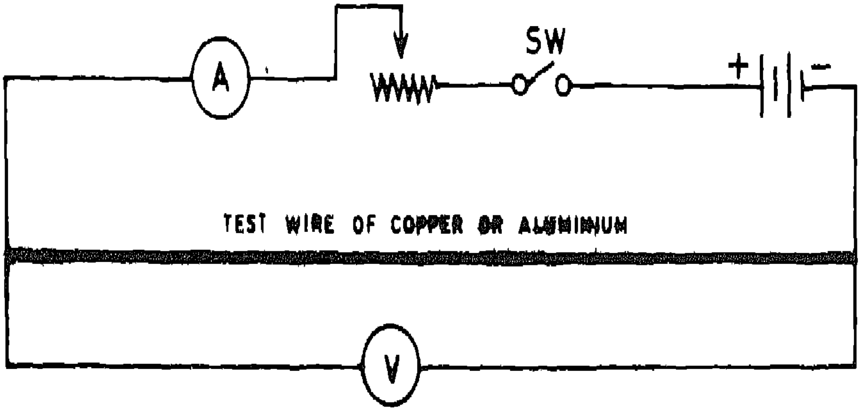


Fig. 1.1 Measurement of resistance by drop test method

Observations

S.No.	*Voltmeter reading V (Volt)*	*Ammeter reading I (Amp/mA)*	*Resistance* $R = \frac{V}{I}$
1			
2			
3			
4			
5			

Draw the graph between ammeter and voltmeter readings.

Precautions

(i) Set the ammeter and voltmeter on zero before using.
(ii) Avoid loose connections.
(iii) Connect ammeter in series and voltmeter in a parallel with the circuit.
(iv) The temperature of the circuit should be kept constant.

Questions

(i) Current varies inversely with . . .
(ii) V = . . .
(iii) Does the measured resistance obey Ohm's law ? If not, why ?

ACTIVITY NO. 2

To Measure Equivalent Resistance of a Series Circuit

Specific Objectives

(i) To observe that the current in a series circuit remains the same

(ii) To measure the drop in voltage across each resistance and the corresponding current as it passes through each resistance

Related Information

Resistance said to be in series when they are connected from end to end like a chain. Their total resistance is known as equivalent resistance and is equal to the sum of the individual resistances

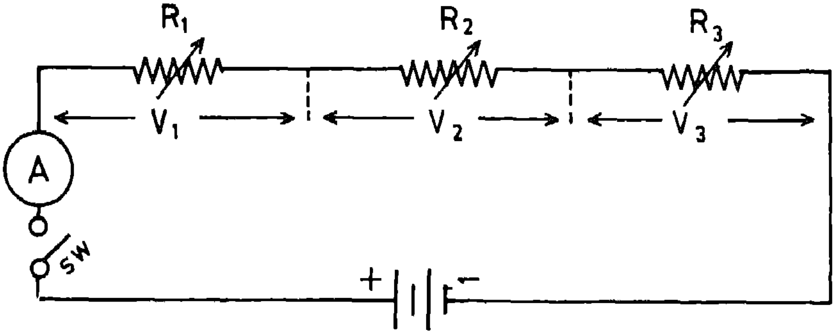


Fig. 2.1 Series resistance circuit

The total resistance or equivalent resistance of the circuit is equal to the sum total of the individual resistances i.e., $R_t = R_1 + R_2 + R_3$. When the resistance of a circuit is to be increased several resistances are connected in series.

In a series circuit the same current flows through resistances and circuit. Voltage drop in the circuit is the sum total of voltage drop across each resistance.

Three resistances R_1, R_2 and R_3 be connected in series as shown in Fig 2 1

$$V = V_1 + V_2 + V_3$$

$$V = IR$$

$$V = IR_1 + IR_2 + IR_3$$

$$\therefore \quad IR = I(R_1 + R_2 + R_3)$$

$$R = R_1 + R_2 + R_3$$

Equipment and Materials

(i) Battery 12 V—1
(ii) Resistances—8 ohms, 10 ohms, 6 ohms
(iii) Voltmeter DC—0 to 12 V
(iv) Ammeter DC—0 to 1 A

Procedure

(i) Connect the resistances in series as showin in Fig.2.1.
(ii) Connect ammeter, switch and battery as per the circuit.
(iii) Measure the voltage across the battery (VB).
(iv) Measure the drop in voltage across each resistance (V_1, V_2, V_3)
(v) Note the ammeter reading (I).
(vi) Repeat the experiment by varying the resistances.

Precautions

(i) Select the instruments of proper range.
(ii) Avoid loose connections.

Observations

Tabulate the results in the following table:

Volt-meter reading	VB (volts)	V_1(volts)	V_2(volts)	V_3(volts)
Ammeter reading	I(A)	I(A)	I(A)	I(A)
R=V/I in ohms	R_T	R_1	R_2	R_3

R(Total) $= R_T = R_1 + R_2 + R_3$

Questions

(i) What is a series circuit?
(ii) Calculate equivalent resistance when three resistances of 5 ohms, 3 ohms and 2 ohms are connected in series.
(iii) What happens when one of the resistances is open?

ACTIVITY NO. 3

To Measure Equivalent Resistance of a Parallel Circuit

Specific Objectives

(i) To measure resistance in a parallel circuit by voltmeter and ammeter methods.

(ii) To find equivalent resistance of a parallel circuit.

Related Information

Several resistances are joined in such a way that one side of all resistances is connected at one point, and the other side at another point. The circuit thus obtained is called parallel circuit. This is illustrated in Fig. 3.1

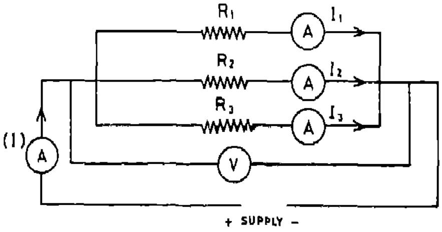


Fig. 3.1. Parallel resistance circuit

In this circuit three resistances R_1, R_2 and R_3 are connected in parallel across a supply of V volts and a total current of I ampere is made to flow through the circuit.

I_1, I_2 and I_3 are the branch currents flowing through R_1, R_2, and R_3, respectively

From Fig. 3 1

$I = I_1 + I_2 + I_3$

But the voltage remains the same across each resistor in a parallel circuit.

$$\text{So, } I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\text{or } I = V\left(\frac{I}{R_1} + \frac{I}{R_2} + \frac{I}{R_3}\right)$$

But $I = \frac{V}{RT}$ where RT is the total resistance

$$\text{So } \frac{V}{RT} = V\left(\frac{I}{R_1} \div \frac{I}{R_2} + \frac{I}{R_3}\right)$$

$$\frac{I}{RT} = \left(\frac{I}{R_1} + \frac{I}{R_2} + \frac{I}{R_3}\right)$$

Thus when two or more resistances are connected in parallel, the equivalent resistance will be less than the least of the individual resistance in the circuit.

Whenever more current is to be distributed in a circuit, it can be done by the parallel combination of resistance.

Equipment and Materials

(i) Battery 12 volts (V) — 1

(ii) Resistances — 6 ohms, 8 ohms and 4 ohms
(iii) Ammeter DC 0 to 10 A — 1
Ammeter DC 0 to 5 A — 3
(iv) Voltmeter DC, 0 to 12 V — 1

Observations

Record ammeter and voltmeter readings in the table below:

Voltmeter reading	V = supply voltage (Volts)			
Ammeter reading in amps	I	I_1	I_2	I_3
$R = \frac{V}{I}$ ohms	$R_T = \frac{V}{I_1}$	$R_1 = \frac{V}{I_1}$	$R_2 = \frac{V}{I_2}$	$R_3 = \frac{V}{I_3}$
Reciprocal	$\frac{I}{R_T} =$	$\frac{I}{R_1} =$	$\frac{I}{R_2} =$	$\frac{I}{R_3}$
$\frac{I}{R_T} =$	$\frac{I}{R_1} +$	$\frac{I}{R_2} +$	$\frac{I}{R_3}$	

Procedure

(i) Connect the resistances in parallel shown in Fig. 3.1.
(ii) Complete the circuit by connecting voltmeter and ammeter as shown in Fig. 3.1.
(iii) Note the voltmeter reading (v) and note the ammeter readings I, I_1, I_2 and I_3.

Precautions

(i) Select the instruments of proper range.
(ii) Avoid loose connections.

Questions

(i) What is a parallel circuit?
(ii) Calculate the equivalent resistance when 8 ohms, 10 ohms and 12 ohms resistances are connected in parallel.
(iii) Does the voltage across each resistance change in a parallel circuit?

ACTIVITY NO. 4

To Study the Effect of Temperature on Resistance in a Tungsten Filament Lamp

Specific Objectives

(i) To determine the cold resistance of the lamp using the wattage and voltage rating

(ii) To understand that the brightness of the lamp varies with the voltage.

(iii) To know that the increase in temperature of the lamp filament results in the increase in its resistance.

Related Information

Metal filament lamps are used for lighting purposes. The heating effect of the filament due to current flow causes the lamp to glow. The heating effect of electricity, $H = I^2Rt$ is the principle which determines the working of lights. The lamps are rated in terms of the wattage and the voltage. The resistance of the filament can be found out by using the equation $\frac{V^2}{R} = W$.

The brightness of a lamp increases with the increase in votlage and the lamp fuses when a voltage beyond its ratings is applied At high temperature the metal filaments have a tendency to volatize. This weakens the filament of the lamp. To overcome this effect, inert gases such as argon and nitrogen are used in lamps.

The filament resistance measured at room temperature is known as the cold resistance Usually, it is measured by an ohmmeter

Resistance in metals increase when the temperature is increased The rate at which the resistance increases is known as the temperature coefficient of metal resistance. Temperature coefficient for tungsten and nichrome are 0.0045/°C and 0.0015/°C at 0°C.

Manganin and constant have the least temperature coefficient of resistance that is 0.0000/°C at 0°C.

For this reason standard resistances are made from the same alloys.

Equipment and Materials

(i) Tungsten filament lamp—1

(ii) Dimmerstat 1 KVA 230 V, 5A—1 (variac)

(iii) Voltmeter AC 0-250V—1

(iv) Ammeter AC 0-2.5A—1

(v) Batten holder—1

Procedure

(i) Connect the dimmerstat with the ammeter, lamp and voltmeter as shown in Fig 4 1

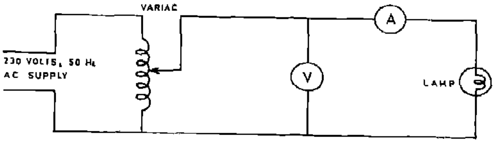


Fig. 4 1 Effect of the temperature on filament

(ii) Increase the voltage slowly by varying the dimmerstat knob.
(iii) Note the voltmeter and ammeter readings when the lamp filament is just red hot.
(iv) Wait for 10 minutes to take the ammeter and voltmeter readings.
(v) Increase the brightness of the lamp by adjusting the dimmerstat and note the ammeter and voltmeter readings.
(v) Calculate the cold resistance of the lamp using the formula, $R = \frac{W}{V_2}$ before starting the experiment.
(vii) Check the cold resistance of the lamp by multimeter (AVO) meter.

Plot the graph: current verses resistance.

NOTE . The experiment can be repeated with metal filament lamps of various wattages.

Observations

S.No	*Voltmeter reading V*	*Ammeter reading I*	*Resistance $\frac{V}{I} = R$*	*Remarks: Brightness of the lamp*
1				Filament just red hot
2				Bright red "
3				Yellowish bright
4				White bright

Cold resistance =

Precautions

(i) Increase the supply voltage gradually.
(ii) Do not exceed the voltage beyond the rated voltage of lamp.

Questions

(i) What is the effect of the temperature on resistance in the case of metals?
(ii) Why are the lamps filled with inert gases ?
(iii) Does the brightness of a lamp vary with the supply voltage ?
(iv) Calculate the resisance of the filament of a lamp rated for 250 volts and 200 watts

ACTIVITY NO. 5

To Study the Effect of Temperature on Resistance in a Carbon Filament Lamp

Specific Objectives

(i) To determine the cold resistance of a lamp using the AVO meter.
(ii) To understand the effect of temperature on the resistance of carbon filament.

Related Information

Carbon filament lamps are generally used for heating purpose but not for lighting. The melting point of carbon being 3500°C the filament starts disintegrating beyond the temperature of 1800°C. So the working temperature of the lamp is low. Its power consumption is high and its efficiency is low. It gives yellowish light and gets blackened at high temperature. Its resistance decreases at high temperatures. This results in drawing more current from the mains. Carbon filament lamps have been superseded by tungsten filament lamps, which are more efficient and can operate at high temperature. The temperature coefficient of resistance of carbon is given as — 0.0005/°C.

Equipment and Materials

(i) Carbon filament lamp 1000 Watts(W)—1
(ii) Batten holder—1
(iii) Voltmeter MIV, 0-125/250V—1
(iv) Ammeter MIA, 0-10A—1
(v) Dimmerstat 1 KVA—1

Procedure

(i) Connect the circuit with the carbon filament lamp and other meters as shown in Fig. 5.1.

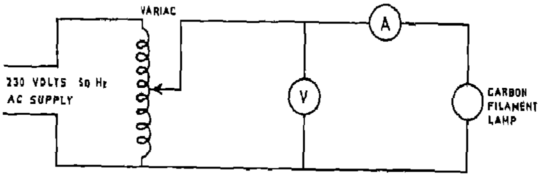


Fig. 5.1 Effect of temperature on carbon filament lamp

(ii) Increase the voltage slowly by varying dimmerstat knob.
(iii) Note the voltmeter and ammeter readings when the lamp filament is just red hot.
(iv) Wait for some time for the lamp to glow (say 10 minutes).
(v) Increase the brightness of the lamp gradually and note the ammeter and voltmeter readings at various stages.
(vi) Measure the cold resistance of the

lamp filament using multimeter (AVO meter).

Observations

S No.	Voltmeter reading V (volts)	Ammeter reading I (amps)	Resistance $R=V/I$ ohm	Condition of the lamp filament
1				Just red hot
2				Bright red
3				Yellowish red
4				yellow

Cold resistance of the filament = Ohms

Plot the graph current vs resistance and compare the curve with that of the metal filament lamp (Ref. Activity No 4) Current vs resistance graph for the tungsten and carbon filament lamps is illustrated in the Fig. 5.2.

Precautions

(i) Do not exceed the operating temperature range.

(ii) Do not exceed the rated voltage while increasing the supply voltage.

(iii) Measure the cold resistance of the filament at room temperature.

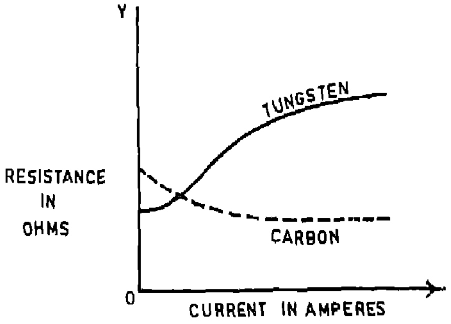


Fig 5.2 Current vs resistance for tungsten and carbon filament

Questions

(i) Why are the carbon filament lamps used for heating and not for lighting ?

(ii) What happens to the carbon filament at high temperature ?

(iii) Why tungsten filament lamps are preferred over carbon filament ?

Activity No. 6

To Study the Types of Fuses

Specific Objectives

- (i) To observe the various types of fuses such as Kit-Kat, HRC and high voltage fuses.
- (ii) To select the proper gauge of fuse wire and to rewire a fuse.
- (iii) To identify the fuses for different (high or low) current.
- (iv) To classify the fuses with respect to their construction and material.

Related Information

A fuse is a safety devise to protect circuit from overload. It consists of a thin piece of wire which is blown off when a high current exceeding the limit flows in the circuit. When the fuse blows out, the circuit is broken and the current ceases to flow, thus protecting the appliance. The fuse is always placed on live wire and is in series with the circuit. The fuse wires are made up of metals like lead, tin, copper etc. which have low melting point There are different types of fuses such as :

- (i) Kit-Kat (rewirable) fuse
- (ii) HRC (High Rupturing Capacity) fuse
- (iii) High voltage fuses

Kit-Kat Fuse : It consists of two parts namely, the fuse-base and the fuse-carrier. They are made up of ceramic materials. The fuse base has two seperate terminals to connect the main wires. The fuse-carrier has two terminals to which the fuse wire is fixed When the fuse-carrier is fixed to the fuse base the circuit is complete through the fuse wire. This type of fuse is popular as it can be easily rewired when it is blown off.

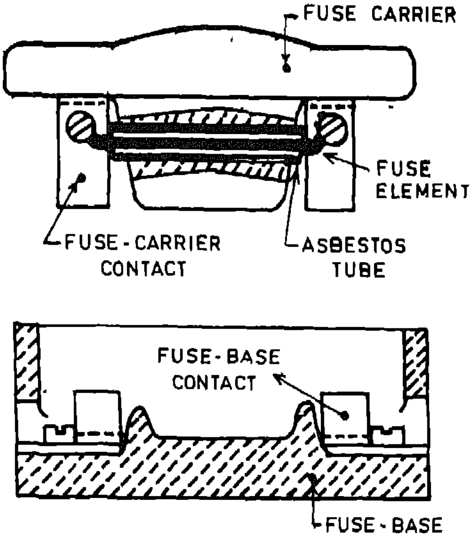


Fig 6.1 Kit-kat fuse

High Rupturing Capacity (HRC) Fuse: This type of fuse is of a cylinderical shape with metallic caps at the two ends. The fuse element is attached in between from end to end. The cylindrical body of the fuse is filled with quartz sand. When high current flows the fuse element melts and vaporises. A new cartridge (fuse) has to be fixed to complete the circuit. The condition of the fuse wire can be checked through the indicator.

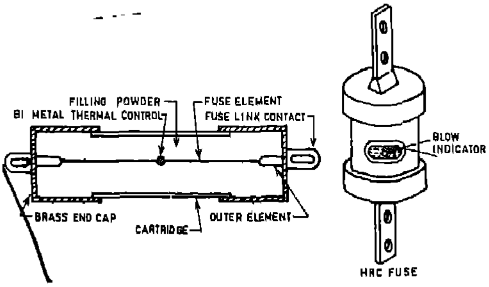


Fig. 6.2 HRC fuse

High Voltage Fuses : Such types of fuses are used in transformer feeder and switch gears of distribution system. Mounted on transmission poles and transformer centre these fuses are operated from ground through gang-operated switches. When the fuse is blown off it drops down and can be easily located.

Procedure

A . Kit-Kat Fuse

(i) Take a Kit-Kat fuse unit, remove the fuse-carrier and observe the construction.

(ii) Remove the fuse wire from the fuse-carrier.

(iii) Refix the fuse wire of an appropriate diameter and length in the fuse-carrier.

(iv) Draw the sketch of a Kit-Kat fuse unit.

B HRC Fuse

(i) Take a cartridge fuse (HRC) and observe its construction.

(ii) Check the cartridge fuse for its continuity.

(iii) Observe the rating of HRC fuse.

(iv) Make a neat sketch of HRC cartridge fuse.

Precautions

(i) Observe the current rating on the fuse carrier while selecting the fuse.

(ii) While replacing the fuse switch off the mains.

(iii) Use the correct material and gauge of fuse wire while replacing the blown-off fuse.

(iv) Cut off the excess length of the fuse wire.

Questions

(i) Name the different types of fuses.

(ii) What are the factors to be kept in mind while selecting a fuse wire ?

(iii) How does a fuse protect an appliance ?

(iv) Why are fuse wires made up of low melting metals ?

ACTIVITY NO. 7

To Study the Fusing Characteristic of Different Types of Fuses

Specific Objectives

(i) To understand the term fusing characteristic of a fuse.
(ii) To determine the fusing current for various wire diameters.
(iii) To determine the fusing current of different materials.

Related Information

The fusing current depends on the length of fuse wire, the diameter of fuse wire and the type of fuse holder.

The fusing current is that value of the current at which the fuse is blown off The current rating of the fuse wire is the value of the current which the fuse wire can carry without melting. This value is less than the fusing current.

Equipment and Materials

(i) A.C. Supply 230 V, 50 Hz
(ii) Rheostat—1
(iii) Ammeter AC 0-15 A—1
(iv) Fuse unit Kit-Kat type—1
(v) Fuse wires of different diameters of the same materials
(vi) Fuse wires of different materials of the same diameter
(vii) Screw gauge

Procedure

(i) Measure diameter of the fuse wires by screw gauge.
(ii) Connect the ammeter, rheostat and fuse unit as shown in circuit diagram, Fig. 7.1.
(iii) Reduce the resistance of reheostat gradually till the fuse blows off and note the current at which the fuse blows.
(iv) Repeat the experiment by replacing fuse wires of different diameters but of the same materials.
(v) Repeat the experiments with fuse wires of different materials such as copper, lead, aluminium.

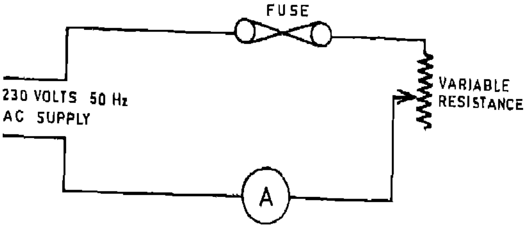


Fig. 7.1 Measurement of fusing current of fuses

Observations

S.No.	*Wire diameter in cm*	*Fusing current in amps*	*Material of the fuse wire*	*Fusing current in amps*
1				Copper
2				Allu-minium
3				Lead and tin alloy wire

Precautions

(i) Do not keep the fuse sagging.

(ii) Always make tight connection.

(iii) Select the proper range of ammeter.

(iv) Be cautious to put off the mains while removing the fuse carrier and replacing it in the circuit.

Questions

(i) What is meant by the fusing current?

(ii) On what factor does the fusing current depends?

(iii) Should the rated current of the fuse wire be higher than the fusing current?

ACTIVITY NO. 8

To Measure the Insulation Resistance and Continuity of a Test Cable by a Megger

Specific Objectives

(i) To understand the working of a megger.
(ii) To connect and use a megger for testing.
(iii) To conduct continuity tests of a test cable.
(iv) To determine the insulation resistance of a cable.

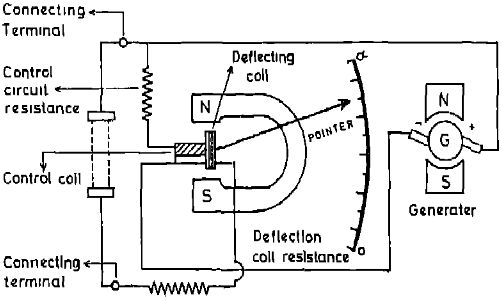


Fig. 8.1 Megger

Related Information

A megger is a portable instrument which is generally used for testing the insulation resistance of electrical appliances and installation. It consists of an ohm meter and a hand-driven D.C. generator. The scale of a megger is caliberated in mega ohms, from zero to infinity. It has two terminals at the bottom to which the test leads are connected. When the handle of megger is rotated, at a uniform speed, the D.C. generator produces about 500 volts for testing.

Insulation resistance test is conducted to know whether the insulation of the conductor is sufficient to withstand the voltage. In motor and transformer windings the conductors are coated with enamel, which acts as insulator. The cables are insulated with PVC or rubber. Insulation resistance is a resistance measured between the conductor and the insulation. One lead of the megger is connected to the conductor (after removing the insulation) and the other lead is connected to the insulating body of the cable. If the insulation is proper, the megger reads a high resistance in the order of megaohms.

In the continuity test the leads of the megger are connected to the two end-terminals of the cable after removing the insulation at the ends. When the megger handle is rotated slightly the pointer moves towards zero position. If the meter reads infinity, it indicates a break in cable continuity.

Meggers are available in various ranges, from 50 megaohms to 50,000 megaohms, generating voltages of 500 volts to 2,500 volts Transistorised meggers are becoming popular as they are easy to operate.

Equipment and Materials

(i) Megger 50 megaohms 500 V—1
(ii) 3-core cable—1 piece
(iii) Test leads—1 pair

Procedure

A. Continuity Test

(i) For continuity test of a test cable, remove the insulation of the test cable at the two ends.
(ii) Separate the cable at the ends for the test.
(iii) Identify the 3-core cable with red, black and green insulation.
(iv) Touch the megger leads to the two ends of the same cable that is red to red, black to black and green to green.
(v) Rotate the handle of the megger on each of the above positions. The megger should read zero if there is continuity in each conductor.
(vi) Record your observations.

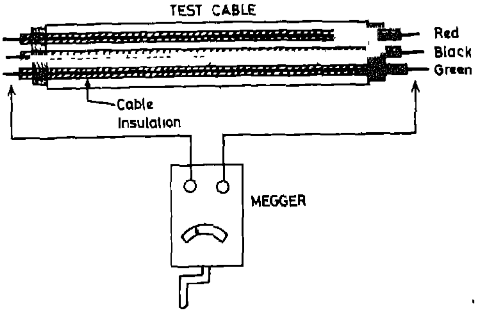


Fig. 8.2 Continuity test

B. Insulation Test

(i) Remove the insulation of cable at the ends and separate them for testing.
(ii) Touch the leads of the megger so that one lead is in contact with the cable and the other lead is with the insulating material.
(iii) Rotate the megger handle.
(iv) Record the observations.
(v) Repeat the procedure for finding insulation resistance between conductors by connecting megger leads to the ends of other cable conductor. (Red to black, black to green and green to red). The megger should read high resistance.

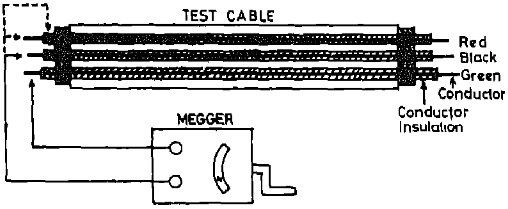


Fig 8.3 Insulation resistance test

Observations

A. Continuity Test

No. of observation	*Megger leads connections*	*Megger reading*	*Remarks*
1	Red to red		
2	Green to green		
3	Black to black		

B Insulation Test

No of observations	*Megger leads connections*	*Megger reading*	*Remarks*
1	Conductor and body insulation		
2	Red to black		
3	Black to green		
4	Green to red		

Precautions

(i) Megger is a delicate instrument, handle it with care.

(ii) Megger testing must not be done on live installation.

(iii) Do not touch the megger terminals (leads) while the handle is rotated.

(iv) Ensure proper connection of megger leads, i.e earth to earth and line to line.

Questions

(i) While conducting continuity test of a cable, the megger reads infinity. What is your conclusion about this ?

(ii) Why should the megger handle be rotated while conducting tests?

(iii) What happens if you touch the leads of the megger when its handle is being rotated ?

(iv) What is an insulation resistance ?

(v) In which units the insulation resistance measured ?

Activity No. 9

To Verify Kirchhoff's Laws

Specific Objectives

(i) To understand Kirchhoff's current law.
(ii) To understand Kirchhoff's voltage law.
(iii) To verify Kirchhoff's laws experimentally.

Related Information

There are two Kirchhoff's laws namely, current law (point law) and voltage law (mesh law). When more than two conductors are joined to make a single junction as shown in the Figure 9.1 the point of meeting these conductors is known as junction node point.

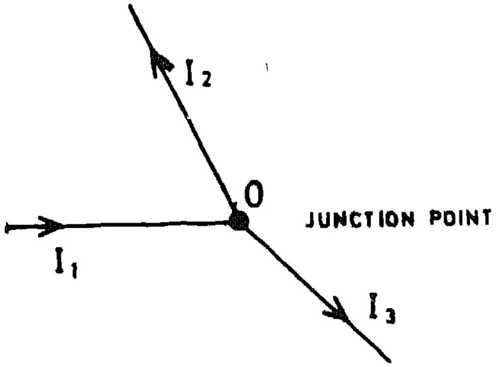


Fig. 9.1. Point law (current law)

When the current I_1, I_2, and I_3 flowing through conductors are considered with reference to the junction O, then it is observed that while I_1 is flowing towards junction I_2 I_3 are flowing away from the junction.

Kirchhoff's current law states that "the algebric sum of the currents at any junction of a network is zero". In other words current flowing away from the junction is equal to the current flowing towards the junction.

From the Fig. 9.1 it can be derived that

$I_1 = I_2 + I_3$

$I_2 + I_3 - I_1 = 0$ (algebric sum).

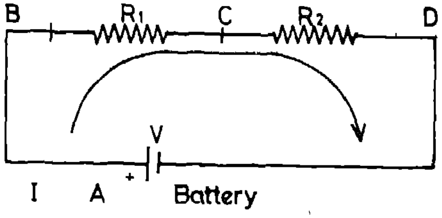


Fig 9.2 Circuit for verification of voltage law

In Fig. 9.2, if we go around the circuit along A B C D A we complete one loop mesh. In the loop a voltage of V is supplied by the battery and a current I is flowing through resistance R_1 and R_2. There is a drop of voltage across BC (i e. across resistance R_1) equals to IR_1.

Similarly, there is voltage drop of IR_2 across CD.

Kirchhoff's voltage law states that "in any closed electrical circuit, the sum of the potential drop (1 × R) is equal to the impressed emf (voltage)".

In the circuit of Fig. 9.2., we have

$I_1R_1 + I_2R_2 + V$

$(V_1 + V_2 = V)$.

Equipment and Materials

(i) Battery 12 V — 1
(ii) Ammeters DC 0-1A — 3
(iii) Voltmeter DC 0-15 V — 1
(iv) Resistance
  10 ohm/15 W — 1
  3 ohm/2 W — 1
  6 ohm/2 W — 1
(v) Switch — 1

Procedure

A. Current Law

(i) Connect the circuit as per the circuit given in Fig. 9.3.

(ii) Switch on the circuit and adjust the rheostat R_1, so that current flows through R_1 and note the ammeter readings A_1, A_2 and A_3 keeping R_1, R_2 and R_3 at the maximum value

(iii) Adjust the rheostat R_1 and change the currents and note the current flowing through A_1, A_2 and A_3.

B. Voltage Law

(i) Refer to the circuit in Fig. 9.3., measure voltage across the battery (V) and across $R_1 = V_1$ and across the combination of R_2 R_3 (V_2).

(ii) Change the position of the rheostat and measure the voltage across R_1, R_2 and R_3.

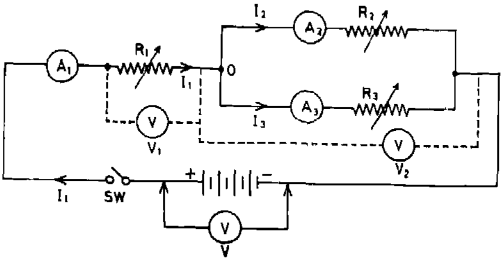


Fig.9.3. Verification of Kirchhoff's laws

Observations

Current Law

S No	Current through Ammeter reading I_1	Current through Ammeter reading I_2	Current through Ammeter reading I_3	$I_2 + I_3$	Current at junction $I_1=I_2+I_3$
1					
2					
3					

Voltage Law

S.No.	Supply voltage V	Voltage drop $V_1 = I_1R_1$	Voltage drop $VI_2 = I_2R_2 = I_3R_3$	$V=V_1+V_2$
1				
2				
3				

Procedure

(i) Avoid loose connections.
(ii) Avoid parallel error while reading meter.

(iii) Set the meters on zero position before connecting in the circuit.
(iv) Hold the leads of voltmeter in the correct position while measuring the voltage.

Questions

(i) State Kirchhoff's current law.
(ii) Distinguish between junction and mesh.
(iii) What do you understand by potential drops?
(iv) Give the equation for the voltage law.

ACTIVITY NO. 10

To Measure Unknown Resistance by Wheatstone's Bridge

Specific Objectives

(i) To be familiar with the Wheatstone's bridge.
(ii) To learn about Wheatstone's bridge connection for measurement of unknown resistance.
(iii) To calculate unknown resistance using the same principle.

Related Information

Wheatstone's network was designed during 1843 by C. Wheatstone, Professor at King's College, London. It provides solution to the network problems in practice and is useful in finding out the value of unknown resistance. The network is as shown in the Fig 10.1.

P, Q, R and S are four resitances connected with a cell of emf E and internal resistance r, across one pair of opposite junction and a galvanometer of resistance G together with very high resistance in series with galvanometer, across the other pair. Value of G is very small as compared with P, Q, R, S. By applying Kirchhoff's first law to different branch junction points current in the different branches can be obtained. The currents are indicated as shown in Fig. 10 1.

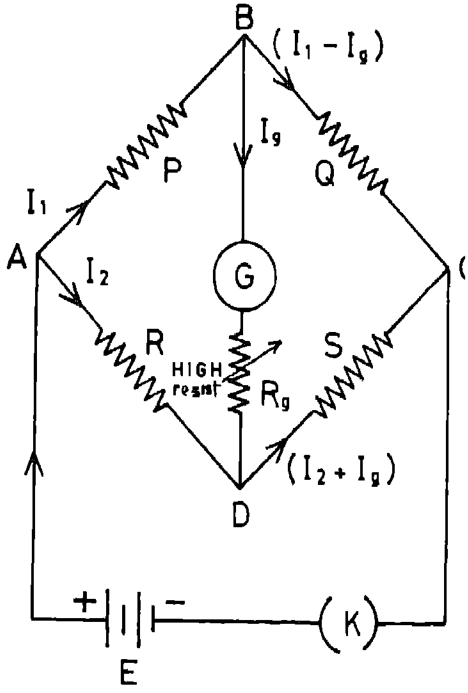


Fig. 10.1. Wheaustone's bridge

Applying Kirchhoff's second law considering the mesh ABDA

$I_1P + I_g(G + R_g) — I_2R = 0$

considering the mesh BCDB

$(I_1 — I_g)Q — (I_2 + I_g) — I_g (G — R_g)$

considering the mesh ADCEA

$I_2R + (I_2 + I_g)S + Ir = E$

where $I_1 + I_2 = I$

If the values of the battery voltage

and the resistances are known, the three equations are sufficient to solve for I_1, I_2 and I_g.

For no current in the galvanometer that is $I_g = 0$ and $R_g = 0$ i.e. balanced condition. First two of the above equations reduce to

$$I_1P - I_2R - 0 \text{ or } I_1P = I_2R$$

$$\text{and } I_1Q - I_2S = 0 \text{ or } L_1Q = I_2S$$

Hence

$$\frac{P}{Q} = \frac{R}{S}$$

When the resistances P_2 Q, R and S are adjusted, so that no current flows through the galvanometer ($I_g = 0$) the circuit is said to be balanced (also the resistances are said to be balanced).

Thus the equation $\frac{P}{Q} = \frac{R}{S}$ gives the balancing condition. Knowing two resistances the other two can be compared. If any three resistances are known, the fourth resistance can be computed.

Slide wire meter bridge : It is one of the practical applications of the Wheatstone's network meter bridge. It conists of a uniform resistance wire A-C, of one meter long which is stretched on a wooden board and soldered at its ends to two thick L-shaped copper strips. This is illustrated in Fig. 10.2. Another copper strip is fixed between them, so as to provide two gaps. The strips provided with the terminals are for making electrical connections. The electrical connections are made as shown in Fig. 10.2 with a resistance R in the left gap and a standard resistance box S in the right gap. A suitable resistance box S is unplugged in the resistance box. The circuit is closed and the position of the sliding contact on the bridge wire is adjusted for zero deflection in the galvanometer. The balancing length is AB and is equal to L. The resistance R of the given wire is obtained as given below.

By the principles of Wheatstone's method

$$\frac{R}{S} = \frac{\text{Resistance of AB}}{\text{Resistance of BC}} = \frac{PL/A}{\frac{P(100\text{-}L)}{A}}$$

$$\frac{R}{S} = \frac{L}{(100\text{-}L)}$$

$$\therefore R = \frac{S \times L}{(100\text{-}L)}$$

Where P = Specific resistance of the wire

A = Cross-sectional area of the wire.

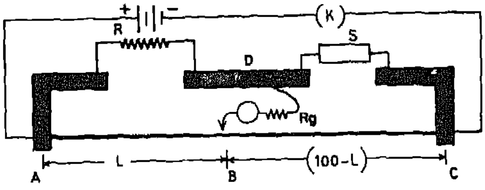


Fig. 10.2 Slide wire meter bridge

Equipment and Materials

(i) Resistance box 1 ohm to 100 ohms—1

(ii) Battery 12 V—1

(iii) Galvanometer 100-0-100 micro amps

(iv) Slide wire meter bridge—1

(v) Keys (switch)

(vi) High resistance 10,000 ohms (Rg).

Procedure

(i) Connect the slide wire with the

galvanometer standard resistance S and the unknown resistance R as per Fig. 10.2, with the battery.

(ii) Move the slide contact provided with one of the leads of galvanometer on the wire. Move the contact till the galvanometer indicates zero with high resistance in series.

(iii) Note the position of strip and measure the length of the wire L from A to B as shown in Fig. 10.2. (A meter scale is fixed from A to C for this purpose.)

(iv) Observe and record the length of the wire from B to C (100 – L)

(v) Calculate the resistance value of the unknown resistance R using the equation

$$R = \frac{SL}{(100 - L)}$$

Observations

S.No	L reading	(100-L) reading	Known resistance S in ohms	Unknown resistance $R = \frac{SL}{(100 - L)}$
1 2 3				

Precautions

(i) Connect the circuit properly.

(ii) Galvanometer should be handled very carefully.

(iii) Read the instrument and record the values correctly.

(iv) Avoid parallax error.

Questions

(i) The value of S is unknown (true/false).

(ii) Galvanometer has the pointer at the centre (true/false).

(iii) On what principle is this experiment based?

ACTIVITY NO. 11

To Study the Phenomenon of Battery Charging

Specific Objectives

- (i) To differentiate between the different methods of charging.
- (ii) To prepare a battery for charging.
- (iii) To charge a battery by the constant voltage method.
- (iv) To charge a battery by the constant current method.
- (v) To test a battery after charging.

Related Information

Lead-acid batteries produce electrical energy by chemical action and store it. They get discharged after constant use. The voltage per cell falls below 2 volts and the specific gravity of electrolyte decreases to 1.125, when completely discharged. Charging of storage batteries is hence absolutely essential to keep them fit for use. On charging, the voltage per cell increases to 2.2 volts on an open circuit and 2 volts on load. Specific gravity of electrolyte increases to 1.28 volts.

Only direct current is suitable for charging the batteries. DC supply may be obtained from any source such as an MG set or a rectifier. Care should be taken to connect the positive of the supply to positive terminal of the battery and negative of the supply to the negative terminal of the battery while connecting it for charging.

A. *Charging Time, Current and Voltage*

Time is an important factor in recharging. High charge current is required to replace the energy taken out of the battery by battery-operated electric trucks or vehicles used in many industries. Charging at a higher rate for a short period is called boost charge. Boost charge should generally be avoided as this reduces the life of the battery. 20 to 30 per cent of the battery capacity can be restored in an hour with the boost charge in case of emergency.

B. *Charging Current*

Normally this must be done according to the recommendations of the battery manufacturer. Generally 1/10 of the ampere hour capacity to 10 hours charge or 20 hours at 1/20 of the ampere hour capacity for slow charge is recommended depending on the time available for charging.

C. *Charging Voltage*

For normal charging generally 2.5 to 2.65 volts per cell is used.

For trickle charge this voltage has to be between 2.2v and 2.3v per cell.

D. *Charging Methods*

Apart from the trickle charging and float charging which are used for the upkeep of the battery there are two methods by which a battery can be charged.

(i) Constant current charging: DC voltage is used for this method. Battery is connected to the DC mains through loading resistance. When the number of batteries are to be charged, they are connected in series. With resistance to the mains same capacity batteries are grouped together. When different capacities batteries are to be connected for charging, the charging current should not exeed the value required for the smallest capacity battery. In order to maintain constant current throughout the charging period, the resistance of the circuit is adjusted frequently during the period. Arrangements for the constant current charging in shown in Fig 11.1.

Charging current can be calculated as·

$$I \text{ charge} = \frac{V - Vb}{R + r}$$

Where

V = Supply voltage
Vb = Voltage across the battery terminals
R = Loading resistance in ohms
r = Internal resistance of battery

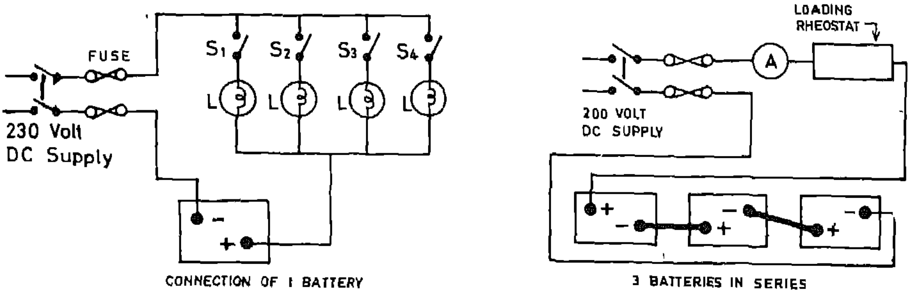


Fig. 11.1. Constant current charging

(ii) Constant voltage charging: A battery charger or a DC source of definite voltage is required for this method. Batteries of the same voltage are connected in parallel to the source. Capacity of the battery need not be the same. Charging current gets adjusted by itself according to the condition of the charge left. Charging voltage is generally set to 2.5 volts to 2.65 volts per cell. Charging current tapers to very low value as the battery gets charged. Once the battery is put on charge no further adjustment of voltage or current is necessary. Arrangement for the constant voltage charging is shown in Fig. 11.2. Most modern charging equipments make use of an A.C. supply with a rectifier to obtain required D.C. This results in safe and flexible control of battery charging either automatically off with minimum manual attention

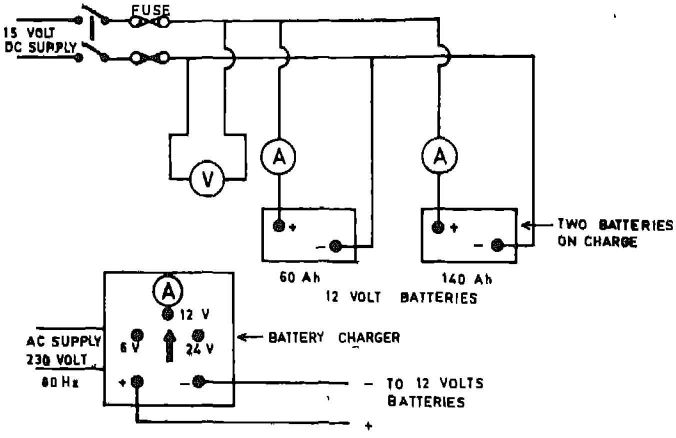


Fig 11.2 Constant voltage charging

(iii) Trickle charging: Trickle charge is usually applied to any low rate charge, in the order of 0.05 to 0.1 per ampere-hour capacity. The trickle charge current is suficient to balance the internal losses of the battery thus keeping the battery in fully charged condition. It is used for maintaining the batteries in charged condition during the lengthy storage period.

(iv) Float charging: Batteries, which are used as a source of steady supply of power in case of emergency, are permanantly connected across the system of load. The battery is floated across the system in parallel with a rectifier charger.

Under true float conditions the battery neither discharges nor charges. In order to keep it functioning and fully charged, a trickle charge is allowed. Under these conditions the battery is operated on float/trickle charge and the number of cells in the battery are selected to ensure that the applied system voltage is equivalent to about 2.15 to 2.20 volts per cell.

Floating battery system of charging is widely used for power station, emergency lighting and telephone exchange installations.

Equipment and Materials

(i) DC source from the rectifier
(ii) Battery charger for 6 V / 12 V supply
(iii) Connecting leads with battery clips
(iv) Distilled water
(v) Petroleum jelly
(vi) Hydrometer

(vii) Cell tester
(viii) High-rate discharge tester
(ix) Variable resistance or lamp with holder and switch
(x) Battery for charging.

Procedure

A. Constant Current Charging

(i) Clean the battery and its terminals.
(ii) Remove the vent plug and check the electrolyte level.
(iii) Top up with distilled water (the distilled water level should be marked on the battery, or 1 to 1.5 cm above the top of the plate).
(iv) Measure the voltage of each cell or the whole battery and check the specific gravity of electrolyte in each cell.
(v) Connect the battery to the supply through lamps or resistance and ammeter as shown in Fig. 11.1 (keep all the switches off).

NOTE: **Check the current polarity of connection, + ve of battery to + ve of supply and –ve to –ve. Avoid loose connections.**

(vi) Adjust the resistance to the highest value or keep all the lamps' switches in off positon. Switch on the main switch.
(vii) Adjust the charging current as per the requirement (example A : Hour capacity 10 or 20) by adjusting the resistance or switching on the required number of lamps.
(viii) Keep a watch on the charging current and adjust it to the constant value throughout the charging period.

* NOTE: **If too much gasing appears and electrolyte starts boiling, reduce the charging current.**

(ix) Leave the battery in the circuit until it is fully charged. Indications of the fully-charged battery are :
  (a) violet gas occurs
  (b) voltage per cell or open circuit increases to 2.2 volt per cell
  (c) specific gravity of electrolyte increases to 1.280.
(x) Disconnect the battery from the charging circuit, check voltage, specific gravity, and test by the high-rate discharge tester for confirming the conditions of the battery. Close the vent plugs properly.

Observations

	TABLE I		TABLE II		
	Voltage per battery	Specific gravity	Charging current	Duration of the charge	Ampere hour capacity
Before charging					
After charging					

B. Constant Voltage Charging

Procedure

(i) Clean the battery and its terminals.
(ii) Remove the vent plug and check the electrolyte level.
(iii) Top it up with distilled water.
(iv) Measure the voltage of each cell of the battery and check the specific gravity of electrolyte in each cell.
(v) Connect the battery charger as per Fig. 11.2, after setting it to the correct voltage (on charger it is indicated as 6 volts, 12 volts, 24 volts etc.)

NOTE: **Check correct porality.**

There should be no loose

connections. In case of variable voltage source adjust 2.5 to 2.65 volts per cell.

(vi) Record charging current (if current is too high reduce the charging voltage).

(vii) Leave the battery in the circuit until it gets full charged.

* NOTE: No adjustment of current or voltage is necessary while in charge, the charging current tapers off to nearly zero when the battery is fully charged Charging current depends on the amount of charge left in the battery)

(viii) Disconnect the battery from the charging circuit. Check voltage, specific gravity and test by the high-rate discharge tester for confirming the conditions of the battery.

(ix) Close the vent plug properly.

Observations

TABLE 1

	Voltage per cell or battery voltage	*Specific gravity*
Before charging		
After charging		

TABLE 2

Charging current in amps	*Duration of the charge (hours)*	*Ampere hour capacity of the battery*

Precautions

(i) Watch the temperature of the electrolyte. (It should not exceed 45°C.)

(ii) Electrolyte can cause injury. Avoid coming in contact with it. Wash with water if you come in contact with it or it falls on your cloth.

(iii) There must be no loose connections.

(iv) Naked flame should not be taken near a battery under charge.

(v) Charging room should be well-ventilated.

(vi) Do not short battery terminals to test its conditions.

(vii) Reduce charging current when building up of the voltage starts.

(viii) Apply petroleum jelly to battery terminals to avoid corrosion after putting it in service.

Questions

(i) If 3 batteries of 40 ampere hour, 70 ampere hour and 140 ampere hour are connected in series for the constant current charge, what should be the maximum charging current that can be used for 10 hours charge?

(ii) What will happen if the battery is reversed-connected (+ve of battery to –ve of supply and –ve to +ve)?

(iii) Name the electrolyte used in lead-acid batteries

(iv) If you have to prepare an electrolyte for the battery, state how will you mix and what precautions are necessary?

(v) One of the cells of a battery shows 1.5 volt even after it was charged for 20 hours. What does this indicate?

(vi) How will you identify the +ve and –ve terminals of a battery if no marking is available on it?

ACTIVITY NO. 12

To Make an Electromagnet and Study the Direction of Current/Polarity

Specific Objectives

(i) To prepare an electromagnet using D.C. supply.

(ii) To change the direction of current and observe the polarity.

(iii) To observe the lines of flux.

Related Information

If an enamelled copper wire is wound around a soft iron core and a current is passed through it, the iron core works like a magnet. But its magnetism is not of a permanent nature and the iron ceases to be a magnet as soon as the flow of the current stops Such a magnet is called an electromagnet.

The polarity of electromagnet depends on the direction in which the current flows. By changing the direction of the flow of current the polarity of the magnet can be changed. The polarity can be checked by a magnetic needle.

The lines of force are the imaginary lines which emanate from the North Pole and terminate on the South Pole. Since the flux lines come from the magnet, they are known as magnetic flux. The flux path in a magnetic circuit is similar to the path of current in an electrical circuit. The magnetic motive force (mmf) is responsible for producing the magnetic effect. This property corresponds to the emf of an electric circuit. The opposition to the path of flux is known as magnetic reluctance which is similar to the resistance in an electric circuit.

$$\text{Current} = \frac{\text{EMF}}{\text{Resistance}}, \text{Flux} = \frac{\text{MMF}}{\text{Reluctance}}$$

The flux path can be observed by sprinkling iron filings on a paper-board which is placed on the electromagnet By tapping the paper, the iron filings form a definite pattern to indicate the lines of magnetic flux path.

Equipment and Materials

(i) M S.rod 2.5cm dia x 10cm long—1

(ii) Enamelled copper wire 20 SWG —10 metres

(iii) Leatheroid paper —15 cm x 15 cm

(iv) Battery 12V —1

(v) Switch —1

Procedure

(i) Wrap the leatheroid paper around the ms rod.

(ii) Carefully wind enamel copper wire in a clock-wise direction uniformally along the length of the rod.

(iii) Scrap the enamel at the ends of

conductor and connect them to the battery as per Fig. 12.1.

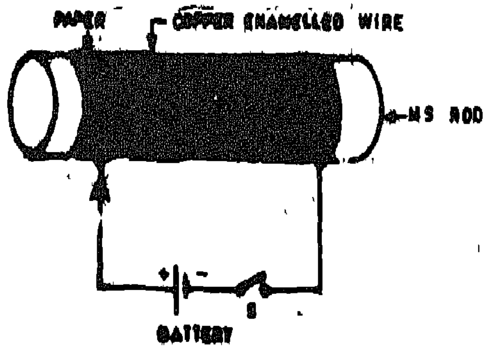


Fig.12.1 Electromagnet

(iv) Close the switch to complete the circuit.

(v) Bring the magnetic needle near the magnet and check whether it is being attracted or repelled (clockwise/anti-clockwise)

(vi) Interchange the polarity of battery terminals and check the deflection of the needle (clockwise/ anti-clockwise) with the help of magnetic needle. If the deflection of the needle in case of (v) above is clockwise, the deflection in the needle will be anti-clockwise now.

(vii) Place a paper board on the electromagnet to form a level surface. Sprinkle iron filling uniformly on the top surface of the paper and tap it slightly.

(viii) Draw the pattern of lines of magnetic flux path.

Observations

S.No.	*Direction of the current*	*Deflection of magnetic needle (clockwise/ anti-clockwise)*
1		
2		

Precautions

(i) Check the M.S rod for the uniform surface

(ii) Remove burrs, if any

(iii) Check the insulation of the wire

(iv) Do not use the wires having bends and kinks with damaged insulation.

(v) Do not strain the battery.

Questions

(i) Why is an electromagnet known as temporary magnet?

(ii) What are the magnetic lines of force?

(iii) What type of magnet is used in an electrical bell?

(iv) How the polarity of electro-magnet is changed?

ACTIVITY No. 13

To Study a Magnetic Circuit

Specific Objectives

(i) To study the relationship between the magnetic strength and the current in an electromagnet.

(ii) To understand the effect of number of turns to the coil on the magnetic strength of an electromagnet.

Related Information

Magnetic field intensity is propotional to the flow of current through the coil of an electromagnet. By increasing magnetising current the strength of electromagnet can be increased. By increasing the number of turns across the length of the coil the strength of electromagnet can be increased. The strength is measured by the magnetic needle.

Note the deflection of magnetic needle from various positions of the magnet for a particular value of current flowing through the electromagnet. Note the deflection when the magnetic strength of an electromagnet is increased. The magnetic needle deflects at various positions as usual.

Equipment and Materials

(i) Battery 12 V—1

(ii) Rheostat 3 ohms/50W—1

(iii) Ammeter DC 0 to 5 A—1

(iv) Copper coils wound on bobins with dia 2.5 cm of different number of turns—2

(v) Switch—1

(vi) M.S.rod 2.5cm dia and 10cm. length—1

(vii) Magnetic needle

(viii) Scale

Procedure

(i) Connect the circuit as shown in **Fig 13.1.**

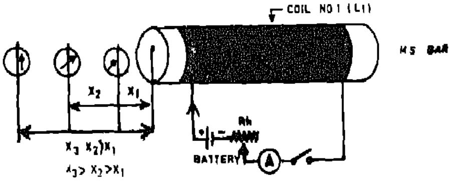


Fig 13.1. Magnetic field strength

(ii) Close the switch and adjust the Rheostat so that current flows through the coil.

(iii) Bring the magnetic needle slowly towards the electromagnet and note the distance at which the needle deflects.

(iv) Increase the current by adjusting the rheostat and note the change of deflection which will give an idea about the strength of magnet by bringing the magnetic needle and measuring its distance from the electromagnet.

(v) Repeat step (iv) with different currents.

(vi) Keep the rheostat position constant and change the coil of electromagnet as per Fig. no. 13.2 (No. of turns may be more or less).

(vii) Check the magnetic strength with the help of magnetic needle. Compare the values obtained in steps (v) and (vii)

Observations

TABLE 1

S No	*Ammeter reading*	*Distance between electromagnet and needle*	*Remarks*
1			
2			
3			

TABLE 2

S.No.	*Coil distance between electromagnet and needle*		*Remarks*
1			
2			

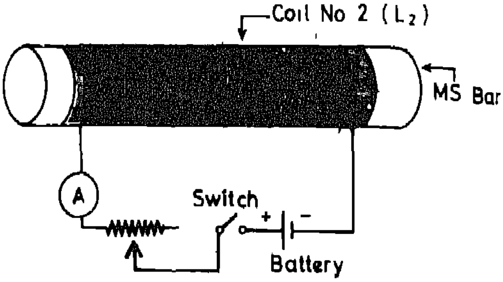


Fig. 13.2 Effect of magnetic strength on coil length

Precautions

(i) Keep the same coil when the current is varied.

(ii) Try to keep the rheostat position more or less at the same position when the coil is changed.

(iii) Measure the attraction point of magnetic needle in the same direction from the magnet throughout the experiment.

Questions

(i) Why does the magnetic needle deflect more when it is brought near an electomagnet?

(ii) Does the magnetic strength change as the current varies in an electromagnet?

(iii) What is the effect of the length of the coil on the magnetic strength?

(iv) What are the advantages of electromagnets over permanent magnets?

ACTIVITY No. 14

To Study the Principle of Mutual Inductance

Specific Objectives

- (i) To construct a model for illustrating the principle of mutual inductance.
- (ii) To measure the induced emf in the secondary coil.
- (iii) To understand the relationship between the induced voltage and the number of turns of the coils.

Related Information

Mutual induction occurs in a coil when a variable flux in produced on an adjacent coil. These two coils need not have direct contact between them. So, when two coils are kept close to each other and a variable current is passed through the first circuit there will be an emf induction in the secondary coil. In such a case the two coils are said to be linked mutually. This principle of mutual inductance is applied in transformer's induction coils etc. Mutual inductance can be defined as "the ability of one circuit to produce an emf by induction when the current in a nearby circuit changes". Mutual inductance is measured in henry.

In Fig. 14.1 we have two coils wound on an iron ring. When a variable voltage is applied to the first coil i.e. primary, induced voltages are noted by means of a voltmeter in the primary coil and the second coil. The ratio of these voltages depends on the number of turns of these coils that is N_1 and N_2, respectively.

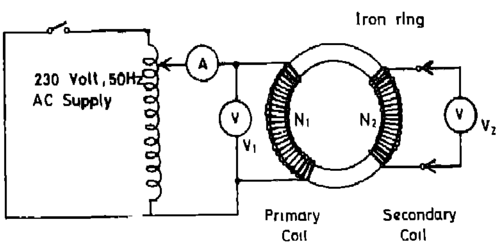


Fig. 14.1 Mutual induction

Equipment and Materials

- (i) Dimmerstat 230 V—1 KVA—1
- (ii) Voltmeter—1 (0-125-250)
- (iii) Ammeter MIV—1 (0 to 1 A)
- (iv) Iron ring — 1 no. (8 cm dia with 6 mm diarod)
- (v) Enamelled copper gauge 20 SWG — 10 meters
- (vi) Enamelled copper gauge 30 SWG — 10 meters
- (vii) Leatheroid paper — 15 cm x 15 cm

Procedure

- (i) Wrap the iron ring with leatheroid paper on the two sides of it as shown in Fig 14.1. Affix it by tying it with thread firmly.

(ii) Wind 20SWG copper wire uniformly on the left side of the ring, say about 200 turns.

(iii) Then wind 30 SWG copper wire uniformly on the right side of the ring, say about 300 turns.

(iv) Remove the enamelled insulation from the ends of two coils.

(v) Connect the first winding (20 SWG) with dimmerstat alongwith an ammeter and voltmeter as shown in Fig. 14.1.

(vi) Connect the voltmeter on the second side (30 SWG wire coil) as shown in the figure.

(vii) Switch on the supply and gradually set the voltage, say about 30 volts.

(viii) Measure the voltage on the second coil.

(ix) Repeat step (viii) by varying the voltage in the first coil and note the voltage on the second coil, and also note the ammeter readings each time. (See any variations in the current with the changes of the voltage).

(x) Interchange connections by connecting supply to the second winding and measure the voltage on the first winding. Here we observe that the voltage in this position is reduced.

(xi) Check the voltage-ratio and turns-ratio of the coil.

(xii) Record your observations.

Observations

	S.No	Voltmeter V1	Voltmeter V2	Ammeter reading A	$\frac{V1}{V2}$	$\frac{V2}{V1}$	Remarks
Observations for steps II to VIII	1						
	2						
	3						
Observations for steps IX and X	1						
	2						
	3						

The ratio of number of turns of the coils equals to $\frac{N1}{N2}$

Precautions

(i) Remove the burrs on the surface of the iron ring.

(ii) Check the wire for proper insulation.

(iii) Increase the voltage gradually.

(iv) Do not connect any load to the second coil.

Questions

(i) Define mutual inductance.

(ii) On what ratio does the induced voltage depends?

(iii) Can the emf induced be changed by changing the ratio of turns?

(iv) In the above step (ix) the change of voltage does not appreciably change the readings of the ammeter. Why?

ACTIVITY No. 15

To Study the Phase Relationship of Voltage and Current in a Circuit Containing Resistance

Specific Objectives

(i) To understand the phase relationship between the current and the voltage in a purely resistance circuit.
(ii) To draw a phasor diagram.
(iii) To calculate the power consumed and also to find out the power factor from the phasor diagram.

Related Information

When a single coil rotates with a uniform angular velocity in a uniform magnetic field, the emf generated is a periodic function of the time represented by an expression of the form $e = E_m \text{ Sin } wt$

where E = instantaneous emf in volts

w = angular velocity of rotation in radian per second and equals to $2\pi f$, f is the frequency in Hz

t = time in sec.

The emf function can also be represented as a radius phasor of length E_m rotating at a rate of w radians per second. The emf may then be considered as a phasor quantity and adding and the subtracting rules of Phasor Algebra may be used. The effective or 'Root Mean Square' is related to the maximum value E_m, when the voltage is represented as a simple sine function by $E = \frac{Em}{V^2}$. Likewise the effective rms value of alternating current is defined in terms of the rate of liberation of energy and may be shown to be related to the maximum instantaneous value by the relation $I = \frac{I_m}{\sqrt{2}}$

In A.C. circuits voltages and currents are expressed and measured in rms values.

In a linear (straight line relationship between voltage and current) A.C. circuit, if the applied voltage is a sine function of time, then the current flowing will also be a sine function, but in general will lead or lag the applied voltage by a constant interval of time. On the basis that 360 electrical degrees represent one complete cycle then, for a given frequency, the time interval between the voltage and the current functions can be represented as an angle expressed in electrical degrees. This angle is called the phase angle of the A C. circuit.

For the resistance the current is propotional to the voltage applied and hence for a sinusodial voltage, the current is given by :

$$i = \frac{Em}{R}\,\text{Sinwt} = I_m\text{Sinwt} \quad \left(\frac{Em}{R} = I_m\right)$$

An inductance opposes any change in the current flowing in the circuit, and it can be shown that the current flowing, where the applied voltage is sinusodial, is

$$i_L = \frac{Em\ \text{Sin}\ (wt - 90)}{X_L}$$

X_L = Inductive reactance in ohm

$X_L = WL = 2\ \pi\ fL$

L = Inductance in henry

Two resistances R_1 and R_2, connected in series, are shown in Fig. 15.1.

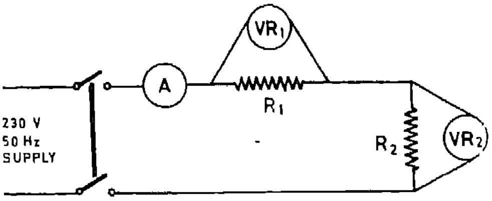


Fig 15.1 Series resistance circuit

Since the resistances are connected in series, the current passing (ammeter reading) through the elements is the same. The voltage drops across the resistances are added up to obtain the supply voltage

$\therefore\ V = V_{R4} + V_{R2}$ (phrasor addition)

$V = V_{R1} + V_{R2}$ (since power factor is the unity).

Equipment and Materials

(i) MIA (0-215A/0-5A)
(ii) MIV (0—125/250V)
(iii) Rheostat . 50 ohms, 100 ohms, 2.5/5.0 amperes with R_1 and R_2 in maximum value.
(iv) Power supply 230V, 50 Hz

Procedure

(i) Connect the circuit as shown in Fig 15.1 with R_1 and R_2 in maximum value.
(ii) Switch on the power supply. (Before switching on the power supply, please recheck the circuit diagram.)
(iii) Vary the resistances.
(iv) Note readings of the ammeter and the voltmeter.
(v) Record your observations in the tabular form given below.
(vi) Switch off the supply and disconnect the elements.

Observations

No. of observation	*Supply voltage V (volts)*	*Ammeter reading (amp)*	*Voltage across R_1 V_{R1}/V_{R2} (volts)*	*Voltage across R_2 V_{R1}/V_{R2} V_{R2} (volts)*	*$V = V_{R1}+$*
1					
2					
3					
4					
5					

Precautions

(i) Measure the voltages across the different elements by connecting the voltmeter leads.
(ii) Always use the appropriate and approved instruments.
(iii) Avoid parallax error while taking the meter readings.
(iv) If a person is electrocuted, DO NOT TOUCH THE VICTIM WITH YOUR BARE HANDS.

Question

(i) From the date sheet calculate the values of R_1 and R_2 as given below:

$$R_1 = \frac{V_{F1}}{I} \text{ and } R_2 = \frac{V_{R2}}{I}$$

ACTIVITY NO. 16

To Study the Phase Relationship of Voltage and Current in a Circuit Containing Resistance and Inductance in Series

Specific Objectives

(i) To understand the phase relationship between the current and the voltage in an inductive circuit.

(ii) To draw a phasor diagram and to find out the phase angle of the circuit.

(iii) To calculate the power consumed and to find out the power factor of the circuit

Related Information

Resistance (R ohms) and inductance (L henry) are connected in series R-L series circuit is shown in Fig. 16.1.

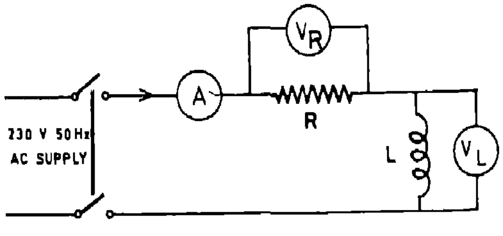


Fig 16.1 Series R-L circuit

The current and voltage relation can be graphically represented as in Fig. 16.2.

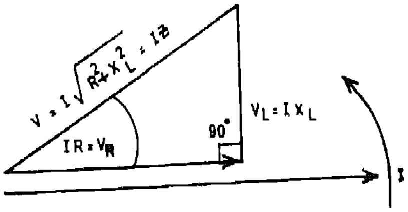


Fig. 16.2 Phasor diagram

R = Resistance in ohms

X_L = Inductive reactance = $2\pi fL$

L = Inductance in henry

Z = Impedence of the circuit

$Z = \sqrt{R^2 + X_L^2}$

I = current flowing through the circuit in amperes.

Voltage across resistance, $V_R = I_R \times R$

Voltage across inductance, $V_L = IX_L$

Voltage across R and L = V = IZ

Cos θ = power factor (lag)

$$\frac{VR}{V} = \frac{IR}{IZ} = \frac{R}{\sqrt{R^2 + X_L^2}}$$

Hence, phase angle can be found with the help of log table,

∴ p = power consumed = VI cos θ watts (Voltage and ammeter readings are in volts and amperes.)

Equipment and Materials

(i) MIV (0-125V/250V)

(ii) MIA (0-2.5A/5A)

(iii) Rheostat 20 ohm (variable)

(iv) Inductance (choke) 0.5 henry

(v) Power supply 230V, 50 Hz

Procedure

(i) Connect the circuit as shown in Fig. 16.1 with R (max) and L.

(ii) Switch on the power supply.

(iii) Vary the resistance.

(iv) Take readings of ammeter and voltmeter.

(v) Record your observations in the tabular form.

(vi) Switch off the power supply and remove the circuit elements

Observations

No of observation	Supply Voltage I (volt)	Ammeter reading I (amp)	Voltage across R = VR (volt)	Voltage across $L = V_L$ (volt)	Power factor	Power consumed
1						
2						
3						
4						
5						

Questions

(i) Draw a phasor diagram on a suitable scale with the current as a reference phasor.

(ii) Calculate $V = I\sqrt{R^2 + XL_2}$

$R = \frac{VR}{I}$ and $X_L = \frac{V_L}{I}$

(iii) Determine Cos θ = Pf.

(iv) Calculate $P = V \times I \times Pf = I_2R$ for each reading.

(v) In a certain circuit it was known that the current was lagging behind the voltage, when measured by means of a voltmeter and ammeter. The effective voltage was found to be 100 volts and the effective current to be 5 amperes. When measured with a wattmeter, the power was found to be 400 watt. What is the power factor of the circuit?

ACTIVITY NO. 17

To Study the Phase Relationship in an A.C. Parallel Circuit Containing Resistance and Inductance

Specific Objectives

(i) To show the phase relationship between the current and the voltage in a parallel circuit containing resistance and inductance

(ii) To draw a phasor diagram with the help of the readings of ammeter and voltmeter.

(iii) To measure the power consumed in the circuit.

Related Information

Resistance R and inductance L are connected across the supply voltage in parallel as shown in Fig. 17.1.

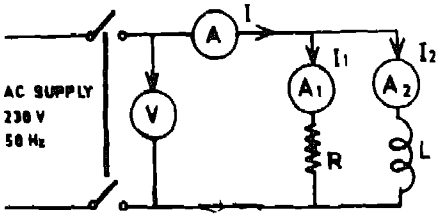


Fig. 17.1 R-L parallel circuit

Total current, I flowing through the circuit, is given by addition of I_1 and I_2

$I = I_1 + I_2$ (phasor addition)

$\therefore$ Total current $I = \sqrt{I_1^2 + I_2^2}$

Power factor is given $\dfrac{I_1}{I}$

$\therefore$ Power consumed = $V \times I \times Pf$

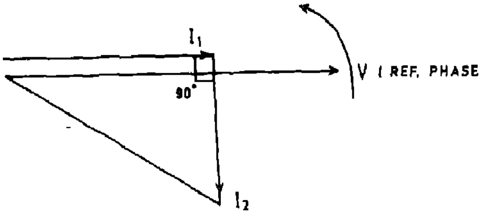


Fig. 17.2 Phasor diagram

Equipment and Materials

(i) MIA (0-10 Amp, 0-2.5/Amp) — 3

(ii) MIV (0-250V) — 1

(iii) Rheostat 70 ohm, 2.5 A — 1

(iv) Supply voltage 230 V, 50 Hz

(v) Air/iron core reactor 0.1 henry.

Procedure

(i) Connect the resistance and inductance as shown in Fig 17.1.

(ii) Switch on the power supply.

(iii) Take readings of the ammeter and voltmeter across the circuit elements.

(iv) Record the readings in the tabular

form for various positions of rheostat.

(v) Switch off the supply.

(vi) Disconnect the circuit elements from the circuit.

(vii) Choose a scale say 1 cm = 0 2 amp to draw the phasor diagram.

Observations

No. of observation	Ammeter reading			Voltmeter reading V (volt)	$I = \sqrt{I_1^2 + I_2^2}$	Remarks
	I_1 (amp)	I_2 (amp)	I(amp)			
1						
2						
3						
4						
5						

Precautions

(i) Make sure that the test probes are insulated properly

(ii) Select the current through the main switch into the instruments. Remember, if in doubt, select a high range and work down.

(iii) Care has to be taken when measuring the voltage above 50 Volts.

Questions

(i) If in a circuit given below 2 amp. current flows through R_1, what current will flow through R_2? (Fig. 17.3)?

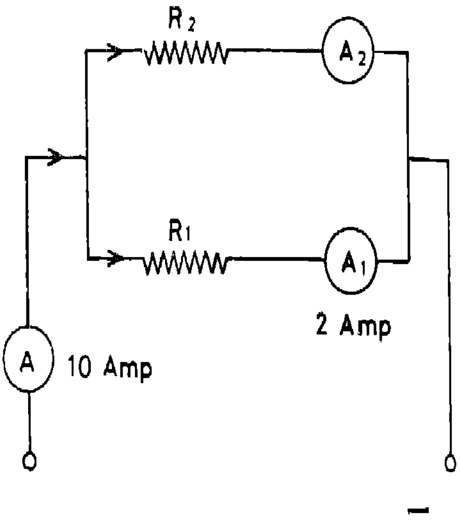


Fig.17.3

(ii) What is power factor? Lagging........Leading.......Unity....?

(iii) Complete the following

(a) $Pf = \frac{R}{?}$

(b) Power consumed = V × ? × Pf.

(iv) In case the total current measured by the ammeter differs from the calculated value from the phasor diagram, justify the difference.

ACTIVITY NO. 18

To Study the Voltage and Current Relationship in an A.C. Parallel Circuit Containing Resistance and Capacitance

Specific Objectives

(i) To show the phase relationship between the current and the voltage in a parallel circuit containing resistance and capacitance.
(ii) To draw a phasor diagram with the help of the readings of ammeter and voltmeter.
(iii) To measure the power consumed in the circuit.

Related Information

Resistance (R ohms) and capacitance (C farads) are connected in parallel. R-C parallel circuit is shown in Fig. 18.1.

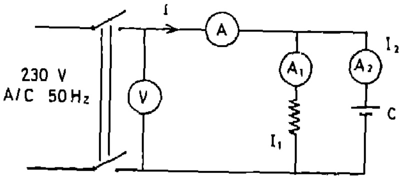


Fig 18.1 Measurement of current and voltage in R and C parallel circuit

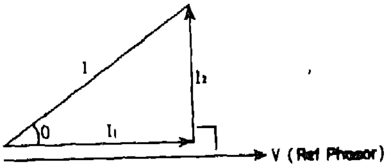


Fig. 18.2 Phasor diagram

$I = I_1 + I_2$ (phasor addition)

$I = \sqrt{I_1^2 + I_2^2}$ amps

Choose a scale to draw the phaso diagram say 1 cm = 0.2 amps.

Power factor, $\cos\theta = \frac{I_1}{I}$

Power consumed P = V × I × Pf (Watt).

Equipment and Materials

(i) MIA (0-10 amp., 0-2.5/5.0 amps)
(ii) MIV (0-250 V)
(iii) Rheostat (variable) 70 ohm 2.5 amp.
(iv) Note pad, pencil and rubber
(v) Capacitor (100 microfarad)

Procedure

(i) Arrange the test circuit as shown in Fig. 18.2 and energise it with 230 V, 50 Hz a.c. supply voltage through the main switch.

(ii) Take readings of ammeters and voltmeter across the circuit elements.

(iii) Vary the rheostat and record the readings of ammeters and voltmeter

(iv) Switch off the supply voltage.

(v) Discharge the capacitor by short circuiting the connecting leads.

(vi) Remove the circuit elements

Precautions

(i) Make sure that the test probes are insulated properly.

(ii) Select the current through the main switch into the instruments. Remember, if in doubt, select a high range and work down.

(iii) Particular care should be taken when measuring voltage above 50 volts.

Observations

No of observation	*Ammeter Reading (Amps)*			*Volt meter Read-ing (volts)*	$I = \sqrt{I_1^2 + I_2^2}$	*Rem-arks*
	A (I)	*I(I_1)(amp)*	*A_2(I_2)*			
1						
2						
3						
4						
5						

ACTIVITY NO. 19

To Study the Charging and Discharging of a Capacitor

Related Information

A capacitor is a device that is purposely constructed and inserted in the circuit to introduce the desired capacitance. Any two conductors seperated by a dielectric (mica, paper and air etc.) have the property of capacitance. Thus, to make a capacitor, all that is necessary is to have two or more metalic plates seperated by air or some other insulation material. The dielectric, in general use, are air, mica, waxed paper, glass, ceramic, oil and, in certain types, gas films.

A. Charging Current of a Capacitor

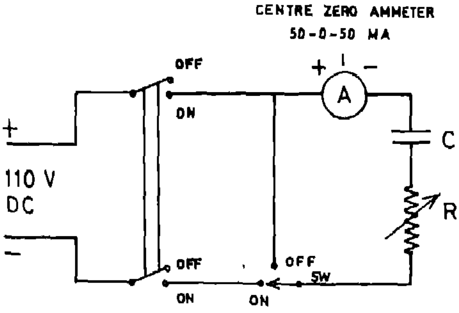


Fig. 19.1. Charging of a capacitor

Fig. 19.1 shows a capacitor of C (five hundred microfarads) being charged through a resistance of R ohms in series with the supply voltage V volts.

Let i = instantaneous value of current. The applied voltage V is consumed by iR drop and V.

Hence

$$V = iR + V \qquad \text{... (i)}$$

We know i = c dv/dt

$$\therefore\ V = CR\frac{dv}{dt} + V \qquad \text{... (ii)}$$

At the instant of closing switch as shown in Fig. 19.1 V = 0 i.e. at the instant of starting

$$V = CR\ \frac{dv}{dt}$$

$$\therefore \frac{dv}{dt} = \frac{V}{CR}$$

$\frac{V}{CR}$ is the initial rate of change of voltage across the capacitor.

The solution of the differential equation (ii) is

$$V = V\left(1 - e\frac{-t}{CR}\right) \qquad \text{... (iii)}$$

Equation (iii) is the equation for the rise of potential across the capacitor during charging period. Rearranging (i)

$$i = \frac{1}{R}(V - v)$$

Subtituting the value of V from equation (iii)

$$i = \frac{V}{R} e \frac{-t}{CR}$$

$$= I e \frac{-t}{CR} \qquad \text{... (iv)}$$

where $I = \frac{V}{R}$ = Steady state current.

CR = Time constant in sec
when C in farad, R in Ohms.

B. Discharging Current of a Capacitor

When the switch is put on off position after charging the capacitor V = 0 and v = V (Refer Fig. 19 1).
Therefore .

$$0 = iR + v$$

$$= CR \frac{dv}{dt} + v \qquad \text{. (v)}$$

$$\frac{dv}{dt} = \frac{-V_q}{CR}$$

$$\therefore v = Ve - \frac{t}{CR} \qquad \text{... (vi)}$$

$$\therefore i = -Ie - \frac{t}{CR} \qquad \text{... (vii)}$$

Theoretically, the relation between charging and discharging current with respect to time as shown in Fig. 19.2 is the same

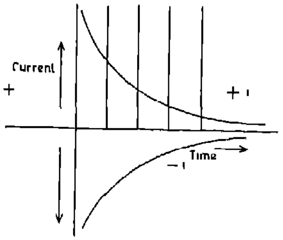


Fig 19 2 Charging and discharging current with respect to time

Equipment and Materials

- (i) Mica capacitor,ceramic disc-capacitor paper capacitor, electrolytic capacitor variable air capacitor
- (ii) DC supply (110 V)
- (iii) Rheostat (10000 Ω 1A)
- (iv) Capacitor (500 microfarad)
- (v) Ammeter moving coil type (0-15mA
- (vi) Voltmeter moving coil (0-150V)
- (vii) Graph paper, pad, pencil and rubbe
- (viii) Stop-watch

Procedure

- (i) Connect the test circuit diagram a shown in Fig 19.1
- (ii) Determine the length of tim required for the current to ris practically to its steady state valu when the voltage (V) is suddenl applied to the circuit with the ai of stop-watch after completion of (ii and (iv).
- (iii) Close the switch (Sw) to 'ON position.
- (iv) Switch on the D.C. mains.
- (v) Observe and record the currents.
- (vi) Repeat for approximately 80, 60, 4 and 20 per cent steady state curren
- (vii) Plot a curve showing rise of curren with respect to time.
- (viii) Determine from the curve the lengt of time required for the current t reach 63.2 per cent of its $\frac{V}{R}$ valu and call this time Tc. Calculate $C = \frac{Tc}{R}$. Using the value of C calculate and plot the current tim graph, using equation (iv) on graph paper with the experimentall determined curve.
- (ix) Switch off the D C mains

(x) Transfer the switch (Sw) on 'OFF' position

(xi) Measure the length of time required for the current to subside to 80, 60, 40 and 20 per cent of its steady state value.

(xii) Plot a curve showing the relation between current and time.

(xiii) Determine from this graph the length of time required for the current to subside to 0.37 $\left(\frac{V}{R}\right)$.

(xiv) By means of this desired equation calculate the various values of i for the various assumed values of t employing the value of C from the experimental current-time graph.

(xv) Plot the theoretically determined points on the same sheet with the experimentally determined points

Observations

Charging Capacitor

No. of observation	*Value of steady state current*	*Time required*
1	100% I =	
2	80 % I =	
3	60% I =	
4	40% I =	
5	20% I =	

Discharging Capactior

No of observation	*Value of steady state value*	*Time required*
1	0.8 I =	
2	0.6 I =	
3	0.4 I =	
4	0.2 I =	

Precautions

(i) Please be sure that the capacitor does not short circuit.

(ii) To test this connect the leads of the capacitor to the AVO meter

Observe :

(a) When the pointer kicks over the scale and then gradually goes down to zero, the capacitor is good.

(b) If the pointer does not move at all the capacitor is supposed to be open

(iii) Special care may be taken to see that the terminals of the capacitor are not short-circuited.

Questions

(i) Two leads of a AVO meter are connected to the two terminals of the capacitor. If the pointer kicks and remains somewhere on the scale and does not return to zero, what do you conclude?

(ii) In the above case : If the AVO meter show zero or nearer to zero, comment on the condition of the capacitor from the following choices: (a) shorted (b) open (c) leaking.

(iii) Assume a charged capacitor is given to you How will you discharge it? A small screws driver is at your disposal.

ACTIVITY No. 20

To Study the Relationship between Phase Voltage and Line Voltage and Phase Current and Line Current in a Three-Phase Star/Delta Connection

Specific Objectives

(i) To find out the relation between the phase voltage and the line voltage in case of star/delta-connected generated three-phase system.

(ii) To determine the relation between phase current and line current of the same system.

Related Information

The 3-phase system is the most extensively used of the polyphase system. The reason for it is that the 3-phase system has the least number of wires in any symmetrical polyphase system Its line voltages are equal, and with a neutral conductor it has the availability of two different values of voltage.

The generation of 3-phase emfs by simple coils rotating in a bipolarmagnetic field is shown in Fig. 20.1. The three simple coils a_1 a, b_1b,c_1 c, fastened rigidly together 120° apart, rotate in an anti-clockwise direction. The shaded sides of the coils are 120° apart, and the terminals a,b,c, from the three sides may be said to be the corresponding terminals. Likewise, the terminals a_1,b_1,c_1 also 120° apart, are the corresponding terminals. Fig. 20.2 shows that the current can be conducted from each of the three coils to the external circuit by means of a pair of slip rings as a_1a,b_1b,c_1c.

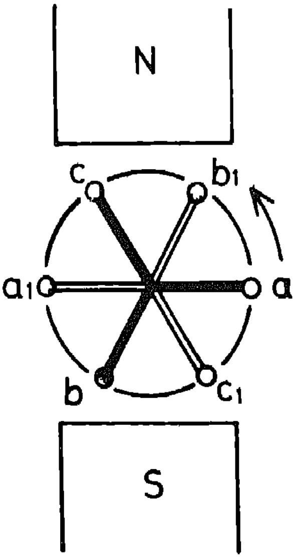


Fig. 20.1 Generation of three-phase emfs

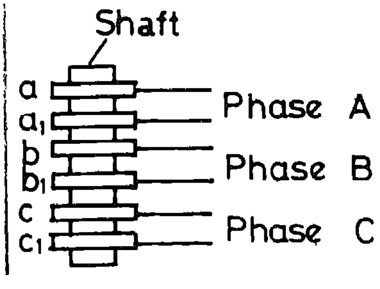


Fig. 20 2 Slip ring connections of an alternator

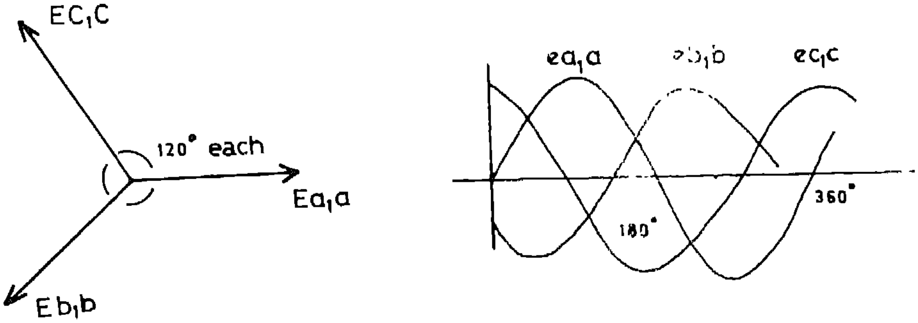


Fig. 20.3 (Instantaneous induced emfs and their phase relationship)

As the instance shown in Fig. 20.1 the emf induced in coil a a_1 is zero and b is increasing in a positive direction; the emf induced in the coil b_1b is approaching its maximum negative value, terminal being negative, the emf induced in the coil c_1c with terminal c positive has passed its maximum value and is diminishing.

In practice, however, a 3-phase alternator seldom supplies independent circuit by the use of six wires, but the phases are combined to give a 3 or 4 wires 3-phase system.

Phase Sequence

Phase sequence means the order in which the three phases obtain their peak or maximum values. In the development of three emfs, anti-clockwise rotation was assumed. This assumption made the emf of phase b lag behind by an angle of 120° and in a similar way, made that of c lag behind that of b by an angle of 120° (or that of by 240°). Hence the order in which the emfs of phases a, b, c, obtain their maximum values is a, b, c It is called the phase order or phase sequence a,b,c

Numbering of Phases

The three phases may be numbered 1, 2, 3, or a, b, c or as is customary, they may be given three colours The colours used commercially, are red, yellow (or sometimes white) and blue. In this case, the sequence is RYB.

Star or Wye (Y) Connection

In this method of inter-connection, the similar ends, say start ends of the three coils (it could be finishing ends also) are joined together at a point n. The point n is called star-point or neutral point.

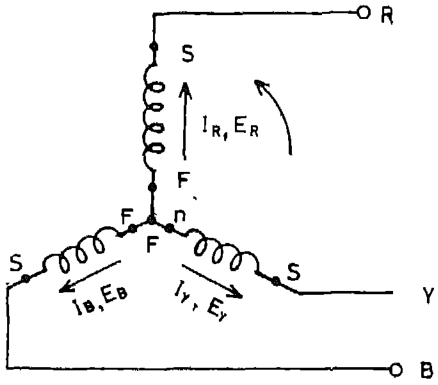


Fig 20 4 Generated emfs and currents distribution in star connection

Such interconnected system is known as four-wire, 3-phase system–

$$\boxed{I_n = I_R + I_Y + I_B}$$

In case of balanced system (phase loads/ currents are equal),

$I_n = 0$

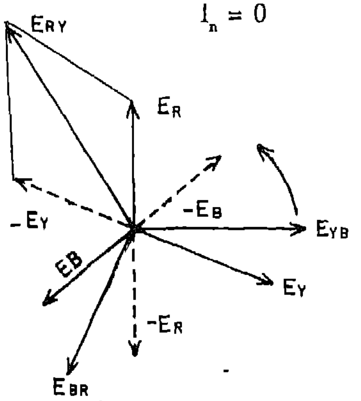


Fig. 20.5 Phasor diagram

The voltage induced in each winding is called phase voltage and the current in each winding is likewise known as phase current. However, the voltage available between any pair of terminals, is called line voltage (V_L) and the current flowing, is called the line current I_L.

The potential difference between the lines R and Y is called $E_{RY} = E_R - E_Y$ (phasor diffrence)

$$E_{RY} = 2 \times E_{ph} \cos \frac{60^\circ}{2}$$

$$= 2\, E_{ph} \cos 30^\circ$$

$$= 2 \times E_{ph} \times \sqrt{\frac{3}{2}}$$

$$= \sqrt{3E_{ph}}$$

Star Connections

$V_L = \sqrt{3} \times$ phase voltage (V_P)

I_L = Phase current (I_P)

E : Stands for generated voltage V : Stands for terminal voltage

Delta or Mesh Connection

In this form of interconnection, the dissimilar ends of the three-phase windings are joined together i e. the starting ends of one phase is joined to the finishing ends of the other phase. The connection is shown in Fig. 20.5.

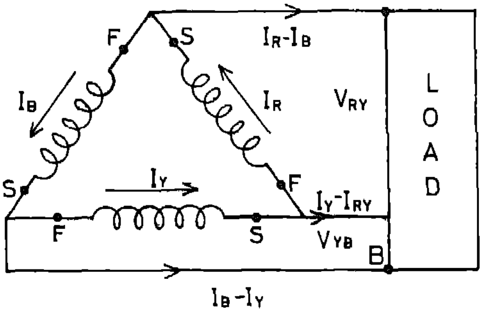


Fig. 20.6

Here, in this case, as seen from the diagram,

$$\boxed{V_L = V_P}$$

Current in line R is $I_L = I_R - I_B$ (phasor difference)

$=\sqrt{3x}$ phase current (I_P)

$$\boxed{I_L = \quad \text{phase current } (I_p)}$$

Equipment and Materials

(i) MIV (0-250V/500V)
(ii) 3-phase 440 supply
(iii) 3 Rheostats (200 ohm, 2 Amp)
(iv) MIA (0-1.00/2.5 Amp)
(v) Note pad, pencil and rubber.

Procedure

(i) Make the connections as shown in Fig. 20.7.

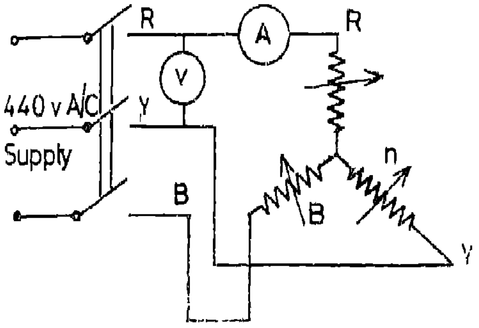


Fig. 20.7

(ii) Energise the circuit by closing the main switch.
(iii) Measure the voltage between R-Y, Y-B, B-R and R-n, Y-n, B-n.
(iv) Record the readings of the ammeter by varying the loads
(v) Switch off the supply voltage.
(vi) Remove the circuit elements.
(vii) Repeat the steps from (i) — (vi) given above for deltaconnected loads.

Observations

No of observation	Star			Delta					Remarks
	V_L			V_p			I		
	VR-Y	V_{YB}	V_{BR}	VR-n	Vy-n	V_{Bn}	IP	IL	
1									
2									
3									

Precautions

(i) Do not work with barefeet
(ii) Every care must be taken to take the readings by putting fingers on the insulated portion of the voltmeter.

Questions

(i) Calculate the relationship between the line voltage and phase voltage for (a) Star connection 3-phase 4 wire 400V, 50 Hz system; (b) Delta connection 3-phase 400V, 50 Hz system.
(ii) Write a few lines on the advantages of 3-phase systems.
(iii) Calcuate theoretical voltages and currents and compare with your results in both the cases.

ACTIVITY No. 21

To Measure Power in a Three-Phase Star/Delta Connected Balanced Lamp Load

Specific Objective

To measure three-phase power in balanced load by an ammeter and a voltmeter.

Related Information

Power

Power per phase (active) $P_p = V_{ph}$ (phase voltage) × Iph (phase current) × Cos θ

In general, power in a phase system
$Pn = n$ (no. of phases) × P_p
$= n \times V_{ph} \times I_{ph} \times \text{Cos}\theta$
Now in case of three-phase n = 3

$$\boxed{\text{Power (p)} = 3 \times V_{ph} \times I_{ph} \times \text{Cos}\theta}$$

In case of Delta circuit :

$$V_{ph} = V_L, \; I_{ph} = \frac{I_L}{\sqrt{3}}$$

$$P = 3 \times V_p \times \frac{I_L}{\sqrt{3}} \times \text{Cos}\theta$$

$$= \sqrt{3} \times V_L \times I_L \times \text{Cos}\theta$$

In case of star, $V_{ph} = \frac{V_L}{\sqrt{3}}$ $I_p = I_L$

$$P = 3 \times V_{ph} \times I_{ph} \times \text{Cos}\theta$$

$$= 33 \times \frac{V_L}{\sqrt{3}} \times I_L \times \text{Cos}\theta$$

$$= \sqrt{3}\, V_L \times I_L \times \text{Cos}\theta$$

Since the loads are resistive the power factor is unity.

Therefore, $P = \sqrt{3}\, V_L I_L$ watts.

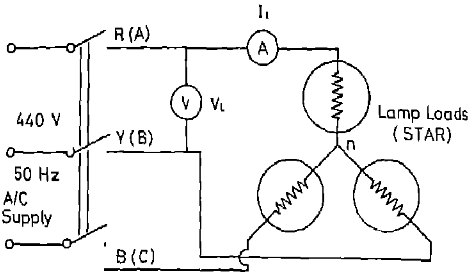


Fig. 21.1 Power measurement in star-connected load

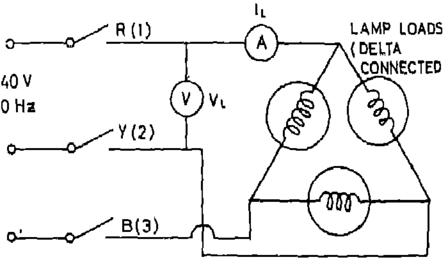


Fig. 21.2 Power measurement in delta-connected load

Equipment and Materials

- (i) MIA (0-1 A)
- (ii) MIV (0 250/500V)
- (iii) Lamp loads/Rheostat (200 ohm, 1.5 (A) (3 nos.)
- (iv) Note pad, pencil and rubber.

Procedure

- (i) Connect rheostats through the ammeter as shown in Figs. 21.1/21.2.
- (ii) With the maximum rheostats/lamps in the circuits switch on the supply voltage.
- (iii) Record the readings of the ammeter by varying the rheostats/lamp loads.
- (iv) Measure the voltage between R-Y, Y-B, B-R by the voltmeter.
- (v) Switch off the supply.
- (vi) Remove the connections.

Observations

No of observation	*Load. star connected*			*Load : delta connected*			*Remarks*
	VL	*I_L*	*W*	*V_L*	*I_L*	*W*	
1							
2							
3							

Precaution

- (i) The test probes must be properly insulated, particularly, when the voltmeter in not connected permanently in the circuit.

Questions

- (i) Draw a) Star connected and b) Delta connected load circuits.

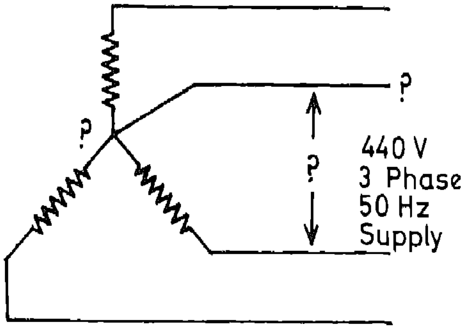


Fig. 21.3

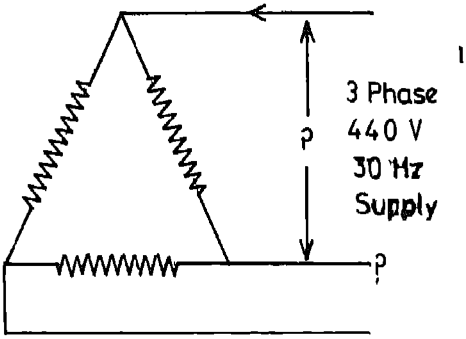


Fig. 21.4

What are the question marks in above the connections?

- (ii) In what connection we get neutral (Star/Delta)?
- (iii) In case lamp loads of sufficient range are not available use rheostat loads.

ACTIVITY NO. 22

To Study the Use of Moving Coil Instruments (Ammeter and Voltmeter)

Specific Objectives

(i) To acquire practical knowlege of the moving coil ammeter (MCA) and voltmeter (MCV).

(ii) To stydy the use of ammeter and voltmeter in practical circuits

(iii) To know the method of connection of MCA and MCV for the measurement of current and voltage.

Related Information

Ammeter: An ammeter measures current in amperes. It is connected in series with the circuit and reads the current flowing through it

- temporarily for test purposes.
- permanent when continuous reading is required.

In parallel circuits where there may be several paths, the ammeter can be placed to

- read the current through the particular path
- read the current through the circuit, i.e. the sum of total current through all the paths.

Voltmeter: A voltmeter measures voltage in volts. It is connected across a circuit and reads the voltage across the components of the circuit

- temporarily for test purposes
- permanently when continuous reading is required.

If there are several paths in parallel, the voltage across each path should be the same.

Electrical instruments are usually of the 'moving iron' or 'moving coil' types. Moving coil instrument has a moving coil and a uniform scale and measures only the direct current quantities.

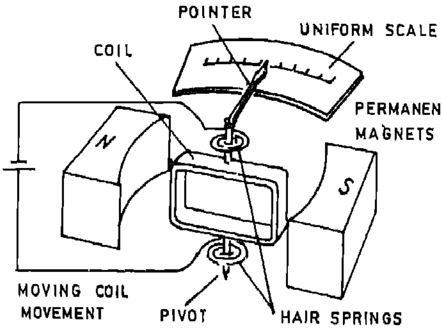


Fig. 22.1 Moving coil instrument

Equipment and Materials

(i) MC Ammeter (0-2.5 A)

(ii) MC voltmeter (0-110 V)
(iii) Rheostat 20 ohm, 5 Amp (variables)
(iv) Rheostat 70 ohm, 2 Amp (variables)
(v) Power supply 230 V, 50 Hz.

Procedure

(i) Connect the rheostats, ammeter and voltmeter as in Fig. 22.2 and switch on the main switch.

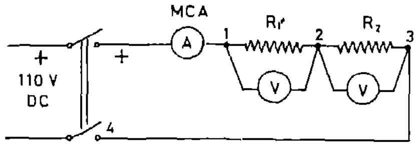


Fig. 22.2 Measurement of current and voltage

(ii) Note the readings of ammeter and voltmeter.
(iii) Vary the rheostat and note the changes in the readings of ammeter and voltmeter.
(iv) Switch off the supply and disconnect the components.

Observations

No of observation	Ammeter reading (A)	Voltmeter reading (V)	
		Across R_1	Across R_2
1			
2			
3			
4			
5			

Precautions

(i) Note that moving coils instruments are used for D.C. only.
(ii) When using D.C. instruments for experiments, it is important to ensure that +ve terminal is connected to the +ve supply and that -ve terminal is connected to the -ve supply. If this is not done the instruments will try to read backward and the pointer mechanism could get damaged.
(iii) The following points, if followed, will ensure proper care of the instruments :
  (a) handle the instruments carefully. They are expensive and can be easily damaged.
  (b) place the instruments in a safe position from where they cannot fall.
  (c) do not let the test leads trail behind when carrying the instruments.
  (d) carry the instruments by the handle.
  (e) do not tap the glass.
  (f) make sure you know how to use the instruments correctly.
  (g) keep the instruments away from the magnets which may affect the readings.
  (h) before using the meter, check that the pointer reads zero. If necessary adjust it by means of the pointer-adjusting screw.
  (i) before use, check the instrument for frayed leads, bent terminals, cracked case, broken glass or a bent and sticking pointer.

Questions

(i) DC is produced by
  (a) ( ) an alternator
  (b) ( ) a rectifier
  (c) ( ) a battery
(ii) Draw a circuit for the measurement of current and voltage in a D.C. circuit.

ACTIVITY NO. 23

To Study the Moving Iron Instruments (Ammeter and Voltmeter)

Specific Objectives

(i) To acquire practical knowledge of moving iron ammeter and voltmeter.

(ii) To study the use of ammeter and voltmeter in practical circuit.

(iii) To know the method of connection of MIA and MIV for the measurement of current and voltage.

Related Information

Ammeter : An ammeter measures current in amperes. It is connected in series with the circuit and reads the current flowing through it :

— temporarily for test purposes

— permanent when continuous reading is required. In parallel circuits where there may be several paths, the ammeter can be placed to :

read the current through the particular path

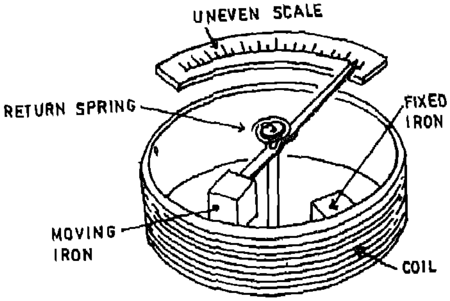
read the current through the circuit i.e. sum of total current through all the paths.

Voltmeter : A voltmeter measures voltage in volts. It is connected across a circuit and reads the voltage across the components in the circuit :

— temporarily for test purposes

— permanently for continuous reading.

Moving iron instrument has a moving iron, an uneven scale and measures both the D.C. and A.C. quantities.



MOVING IRON MOVEMENT

Fig. 23.1

Equipment and Materials

(i) MIA (0-2.5 A)
(0-15 A)

(ii) MIV (0-230 V)

(iii) Rheostat 20 ohm 5 Amp (r1)

(iv) Rheostat 70 ohm, 15 Amp (r2)

(v) Power supply 230V, 50 Hz

Procedure

(i) Connect the rheostats, ammeter and voltmeter as shown in Fig. 23.2 and switch on the main supply.

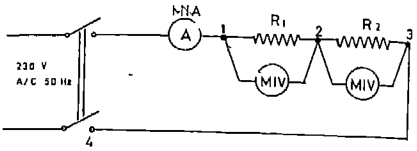


Fig. 23.2 Measurment of current and voltage

(ii) Take the readings of ammeter and voltmeter.

(iii) Vary the rheostat and note the change in the readings of ammeter and voltmeter.

(iv) Measure any D.C. voltage with MIV and note any change with terminals reversed.

(v) Measure the current with MIA in D.C. circuit.

(vi) Switch off the supply and dismantle the circuit.

Observations

No. of observation	*Ammeter reading A*	*Voltmeter reading (V)*		
		Across 1 2	*Across 2.3*	*Across 3 4*

Precautions

(i) MI instruments are used for DC and AC.

(ii) Handle the instruments carefully.

(iii) Check the zero position, before using the meter.

Questions

(i) A.C. is produced by

(a) ( ) a transformer
(b) ( ) a rectifier
(c) ( ) an alternator
(d) ( ) a battery

(ii) Draw a circuit for the measurement of current and voltage using moving iron instruments

ACTIVITY NO. 24

To Measure Power in a Single-Phase Circuit by Wattmeter

Specific Objectives

(i) To acquire practical knowledge of the procedures and precautions involved in the connection of wattmeter in a practical circuit.

(ii) To measure power by wattmeter and also to verify by ammeter and voltmeter readings

(iii) To find out the power factor of the load from the readings of wattmeter, voltmeter and ammeter.

Related Information

Wattmeter

The electrical power consumed in a circuit (DC only) is equal to the product of the current and voltage (watts = ampere × volt). A voltmeter and ammeter may be connected to indicate these values and the power be calculated by multiplying the two readings. For example, if we wish to determine the power consumed by a resistor (R) in a circuit (AC or DC), the meters may be connected as in Fig. 24 1.

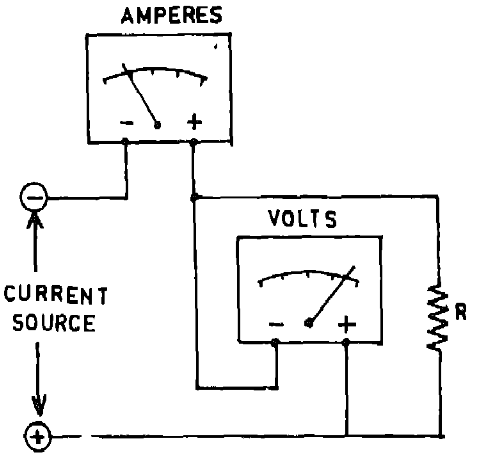


Fig. 24.1. Measurement of power consumed by resistor (R)

The same result may be obtained by using a single instrument of the dynamometer-type connected in the circuit as shown in Fig. 24.2.

The current circuit of the instrument is placed in one line so that it carries the line current provided that current does not exceed the rating of the current coil of the wattmeter. The potential circuit is placed directly across the line voltage provided that the latter does not exceed the rating of the potential circuit of the wattmeter. Many wattmeters are provided with dual ranges of current and voltage. Other factors permitting, the proper choices of the current and potential ranges are those that give the greatest deflection without overloading either the current or the potential circuit.

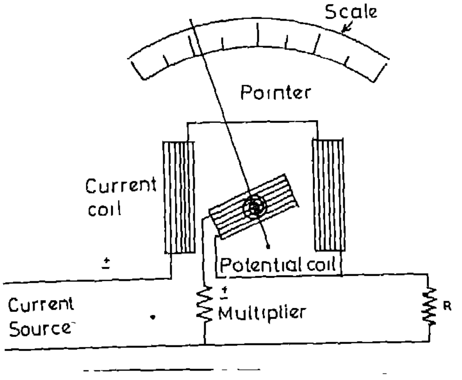


Fig. 24.2

The significance of the polarity markings shown in Fig. 24.2 should be recognised. Note that the current is led into the ± current terminal from one of the supply lines and that the ± potential terminal is connected to that line, either on the 'line' or 'load' side of the current coil. With the relative polarities thus established not only the instrument read up-scale for the absorbed load powers but the two sets of coils will be practically at the same potential level. Its multiplying factor must, in every case, be determined from the lid-data of the instrument.

The two current coils are wound with wire that is heavy enough to pass the current and are connected in series with the circuit under test. Thus, the magnetic fields around them will be proportional to the current flowing in the circuit. The potential coil is connected in series with a resistance (R) and both are connected across the circuit. Thus, they act as a voltmeter, and the magnetic field around the potential coil will be proportional to the voltage. Since the movement of the coil is the result of the interaction of the magnetic fields around the current and potental coils, the movement of the pointer across the scale will indicate the watts being consumed in the circuit. The scale, you will notice, is of a uniform type since it indicates directly, the product of current and voltage.

In A.C. circuit wattmeter readings (average value of true power)

Watts = Voltage × Current × Power factor

$= V \times I \times pf$

In this case, since the load is resistive, the power factor is unity.

$W = V \times I \times 1 = V \times I$

and $pf = \dfrac{W}{VI}$

Equipment and Materials

(i) Voltmeter moving iron (MIV) 0-250V
(ii) Ammeter moving iron (MIA) 0—2.5A/5A
(iii) Rheostat 70 ohm, 5A/200 ohm—2.5 Amp
(iv) Wattmeter 0-250V 0-2.5A/5A
(v) Circuit board
(vi) Note pad and pencil.

Procedure

(i) Connect the rheostat, ammeter and wattmeter as shown in Fig. 24.3 with Rh in maximum position.
(ii) Swith on the power mains.
(iii) Take the readings of ammeter, voltmeter and wattmeter.
(iv) Vary the rheostat and if necessary

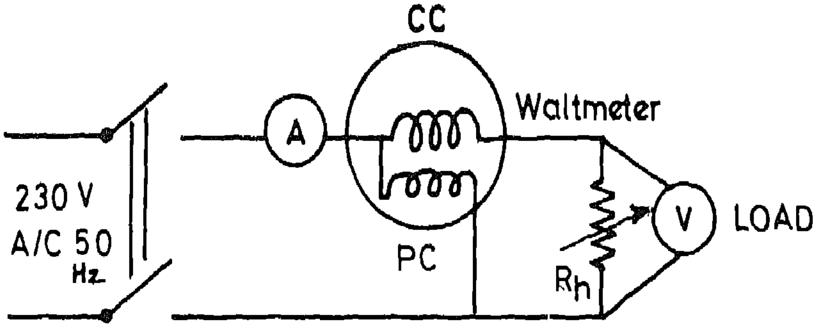


Fig. 24.3

change the rheostat for higher range and take readings of the instruments.

(v) Note the multiplying factor, if any.
(vi) Switch off the main supply.
(vii) Remove the connections of the instruments.

Observations

No of observation	*Voltmeter reading (V)*	*Ammeter reading (A)*	*Wattmeter reading (W)*	*Product of V × I*	*pf = $\frac{W}{V \times I}$*
1					
2					
3					
4					
5					

Precautions

(i) Make sure that the connecting leads are insulated properly.
(ii) Attention should be given to the following details:
(a) Distinction between the current potential coils.
(b) Correct placement of the current coil and potental coil in the circuit.
(c) Knowledge of the correct multiplying factor to use under the various conditions of operation.
(d) Avoid parallex error.
(e) Before using the meter check that the pointer reads zero.

Questions

(i) What will happen to the instruments in case the terminal connections of the current coil is connected across the load?
(ii) State why the wattmeter should be operated in the position for which it is designed—namely, vertical, horizontal or inclined?
(iii) Is it possible to calculate the power factor of load from the phasor diagram?

ACTIVITY NO. 25

To Measure Energy in a Single-Phase Circuit by Energy Meter

Specific Objectives

(i) To be aware of the connections of an energy meter.

(ii) To take readings of an energy meter.

Related Information

Induction type energy meter is an integrated type of instrument. It gives the total energy (in Kwh) consumed by a load in a given period of time. The instrument consists of a disc whose revolutions are proportional to the energy consumed by a load over a given period. Every energy meter is rated for a number of revolutions per Kwh. For example 1200 r p.m per kwh means: When the disc completes 1200 revolutions, one unit of energy has been consumed. The revolving system is connected to the gear train which registers digitally, on the dial the units read by the energy meter. A dial of an energy meter is shown in Fig. 25.1. The readings as registered in the dial of the meter is 0234.06 Kwh. Internal connections of an energy meter is shown in Fig. 25.2.

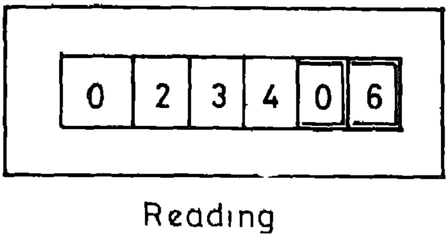


Fig. 25.1

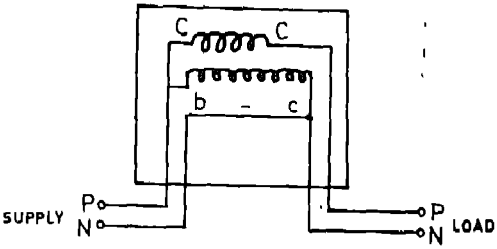


Fig. 25.2

Energy meter is connected to the supply and the load is shown in Fig. 25.3.

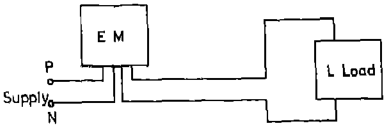


Fig. 25.3

Equipment and Materials

(i)	Energy meter	0-10A, 230V, 50 Hz	—One
(ii)	Supply system	230V, 50 Hz	—One
(iii)	Load	A bank of 200 W (bulbs) (10 Nos)	

Procedure

(i) Connect the circuit as shown in Fig. 25.3.

(ii) Switch on the supply and the full load (2 Kw).

(iii) Take the readings every 15 minutes, for one hour.

Observations

Load = 2 Kw, Meter Rating. ... .Rev/Kwh

S.No.	*Time (minutes)*	*Energy meter reading (Kwh)*	*Remarks*
1	0-15		
2	15-30		
3	30-45		
4	45-60		

Precautions

(i) There should not be any creeping error in the energy meter i.e.meter disc should not rotate in either directions when full voltage is applied but the load is zero.

(ii) Switch on the full load and then switch on the supply.

(iii) Use shades to avoid glare.

Questions

(i) Differentiate between the power and energy.

(ii) Explain the working principle of an A.C. energy meter.

(iii) What do you mean by creeping error?

(iv) In which case the disc will rotate faster, when load is 2 Kw or 1Kw?

(v) Name the quantity being measured by an energy meter.

ACTIVITY No. 26

To Caliberate a Single-Phase Energy Meter with the Help of a Substandard Energy Meter

Specific Objectives

(i) To calculate percentage error.

(ii) To use this error to get correct readings from the instrument.

Related Information

Energy meter is an integrated type of instrument used for measuring the quantity of electrical energy consumed by a load. It may give incorrect readings due to the following reasons :

(i) frictional error

(ii) braking error

To compensate the error, its revolutions are controlled according to the requirement, with the help of braking magnet and compensating arragements. The speed of a rotating disc may by increased by moving the braking magnet in the outward direction and may be decreased by moving the magnet in the inward direction. The frictional error may be compensated by friction-compensating device. The over-compensated frictional error causes another error known as the creeping error and the meter runs when only the shunt magnet or pressure coil is excited.

For the calibration of an energy meter, time taken for a particular number of revolutions is noted in both the energy meters seperately while connected with the same load. Since the ratings of two energy meters are the same (i.e. 1200 rev/Kwh) the consumed energy shown by the two energy meters will be proportional to the time recorded, in case the revolutions and load are the same for both the energy meters. Thus, we come to the conclusion that the energy is proportional to the time. So we plot a graph directly of time recorded by each energy meter. Thus by knowing the times for both the energy meters, error and percentage error can be calculated.

Calibration of energy meter means to compare the readings taken for the same load, by a substandard meter and a test energy meter and find out the error, if any, for necessary action.

Equipment and Materials

(i)	Sub-standard energy meter	1	10A, 250V 1200 rpm
(ii)	Commercial energy meter	1	10A, 250V 1200 rpm
(iii)	Stop watch	1	
(iv)	Lamp board	1	
(v)	Lamps	6	200W, 250V
(vi)	Connecting wire	assorted	15A, 250V

Procedure

(i) Electrical connections are made according to the circuit as shown in Fig. 26.1.

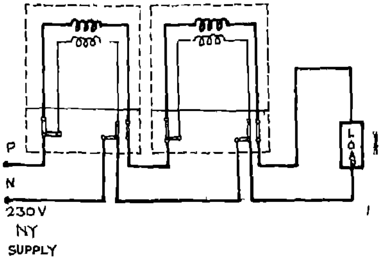


Fig. 26.1

(ii) The energy meters are allowed to rotate for about 15 to 20 minutes to get a steady temperature.

(iii) At a fixed load, the time taken by each energy meter for 20 revolutions are noted seperately.

(iv) The time taken by each energy meter for 25, 30, 35, 40, 45 and 50 revolutions respectively are noted separately for the same load.

(v) The errors and percentage errors are calculated and graphs are plotted.

Observations

S No	*No of revolutions*	*Time taken by testing sub standard energy meter Ts*	*Time taken by testing energy meter Tt*	*Error Tt-Ts*	*Percentage error Tt-Ts×100*
1					
2					
3					
4					
5					

Result

The graph plotted between (Ts and Tt) both the energy meters is a straight line and the graph between Ts and percentage error is a hyperbolic curve.

Precautions

(i) Before carrying out the test, the meters are allowed to rotate for about 15 to 20 minutes so that they may attain a steady temperature.

(ii) The frequency and voltage applied should be according to the rated values of the energy meter.

(iii) The time for a fixed number for revolutions should be recorded carefully.

Questions

(i) What errors might occur in an energy meter?
(ii) What is meant by creeping error in an energy meter?
(iii) How can the braking error of an induction-type energy meter be adjusted?
(iv) On what principle does an A C. energy meter work?
(v) What do you mean by the Board of Trade unit?
(vi) What are the temperature and frequency errors as related to the energy meters?
(vii) Why there are holes in the three rotating discs?

ACTIVITY NO. 27

To Measure Earth Resistance by an Earth Tester

Specific Objective

To be aware of the range resistance of earth, its importance and factors influencing the value of earth risistance.

Related Information

Soil makes a low resistance path for electric current. The value of earth resistance usually varies in the range of 0 5 to 8 ohms. The maximum permissible value according to the I.S. codes is 8 ohms. The value of the earth resistance depends on moisture. It decreases as the moisture increases. It can also be reduced by adding some chemicals such as salt, coal, etc. Earth resistance can be measured by a device known as Earth Tester. A circuit for measurement of earth resistance is shown in Fig. 27.1.

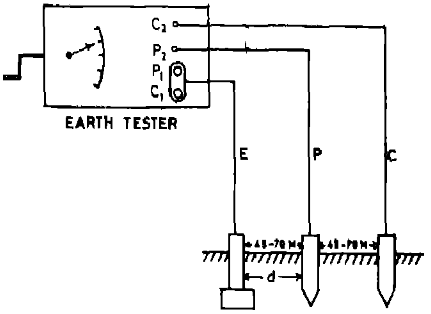


Fig. 27.1

Equipment and Materials

(i)	Earth tester	— one
(ii)	Spikes (M.S.) 2m	— three
(iii)	Measuring tape	— one
(iv)	Connecting wire	— length as required

Procedure

(i) Insert steel spikes in the soil at a uniform distance from each other.

(ii) Make the connections as shown in Fig. 27.1.

(iii) Set the pointer of the earth tester at zero.

(iv) Move the handle of the earth tester with the minimum speed as mentioned in its manual (approximately 130 R P.M).

(v) Note the readings of the earth tester.

(vi) Observe the tester readings by varying the distance between the spikes

Observations

Observe the earth tester readings by varying the distance between the spikes.

S. No.	*Spacing between spikes (EC↓D) E-P,P-C*	*Readings of the earth tester (ohms)*	*Average resistance*
1			
2			
3			
4			

Results

(i) The mean value of the earth resistance is.......

(ii) Plot a graph between the earth resistance and the distance between the spikes ER vs D (E-P)

(iii) A graph showing the relationship between the earth resistance and the distance between the spikes is shown in Fig. 27.2.

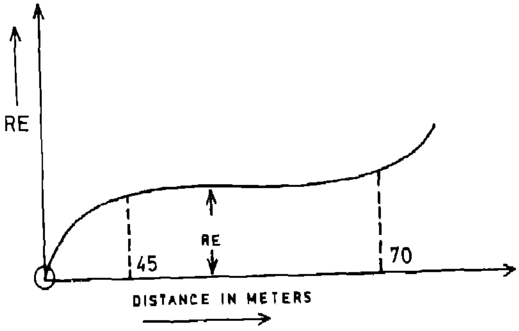


Fig. 27.2

Precautions

(i) The setting of the pointer of the earth tester at zero should be done before taking each reading

(ii) The revolution of the earth tester's handle should not be below the rated speed.

(iii) Each reading of the earth tester should be taken after removing the parallex.

(iv) The readings should be taken strictly when the needle attains its steady state position.

(v) The depth of the spikes in the soil should not be more than the length of the spikes.

Questions

(i) What is the common range of the earth resistance?

(ii) What should be the maximum value of the earth resistance as per I.S.I rules?

(iii) How do you reduce the value of the earth resistance?

(iv) What should be the standard length of the spikes?

(v) How much spikes should be inserted in the earth?

(vi) What should be the standard distance between two consecutive spikes?

(vii) What voltage is generated by the earth tester for measuring the earth resistance?

(viii) What is the value of earth potential?

(ix) Why do you want to reduce the value of earth resistance?

ACTIVITY NO. 28

To Study Multimeter and Its Uses

Specific Objectives

(i) To be aware of the different functions of a multimeter.

(ii) To measure resistance, AC/DC voltages and currents by multimeters.

Related Information

A multimeter is commonly known as AVO meter. It is basically a combination of ohm-meter, ammeter, and voltmeter (AC/DC) with different ranges. It can be used to measure ohms, amperes or volts in any circuit. A multimeter has three type of selector switches, for selecting quantity, supply, voltage and range :

- one for quantity to be measured i.e. current, voltage or ohms
- second for the type of supply, AC/DC
- third for ranges in Amps/Volts.

The students should be familiar with these selector switches before using the meter.

Equipment and Materials

(i)	Multimeter		— one
(ii)	Wire wound resistances	100,200 and 400 ohms	— one each
(iii)	AC source	230V, 50Hz	— one
(iv)	DC source	230V	— one
(v)	Bulbs	100w, 60w, 40w	— one each
(vi)	Battery	6V	— one
(vii)	Rheostat	100 ohms	— one

Observations

S.No.	*Value of resistance*	*Value of AC current*	*Value of DC current*	*Value of AC volt*	*Value of DC volt*
1					
2					
3					
4					

Procedure

(i) Study the selector switches and its ranges of the multimeter to be used.

(ii) Make proper settings for the selector switches for the measurement of AC/DC current, voltage or resistance.

(iii) Insert the probes in the meter and connect it across the unknown resistance and measure its value.

(iv) Make D.C./A.C. circuits and measure the values of AC/DC current and voltages with the multimeter.

(v) Change the values of current and voltage by using a rheostat and take different readings.

Precautions

(i) Ensure proper selection of selector for measurement.

(ii) Always use probes for voltage measurements.

Questions

(i) What is a multimeter?

(ii) Why is multimeter known as AVO meter?

(iii) Why are dry cells required in a multimeter?

(iv) What is the advantage of providing probes?

ACTIVITY NO. 29

To Measure the Transformation Ratio of a Single-Phase Transformer

Specific Objectives

(i) To be familiar with the construction, working principle and function of a transformer

(ii) To measure and calculate transformation ratio

Related Information

A transformer is a static device to set up or down the voltage without the change in frequency at a minimum loss.

A transformer consists of an iron core. On the two limbs of the core there are two windings, having different number of turns When one side is connected to the A.C. supply an alternating flux is set up in core and the e m f. is induced in the second winding as per the principle of mutual induction. Construction of a single phase transformer is shown in Fig. 29.1.

Core is made of silicon steel to reduce the hysteresis losses and is further reinforced by laminations to reduce the eddy current losses.

The winding to which supply is

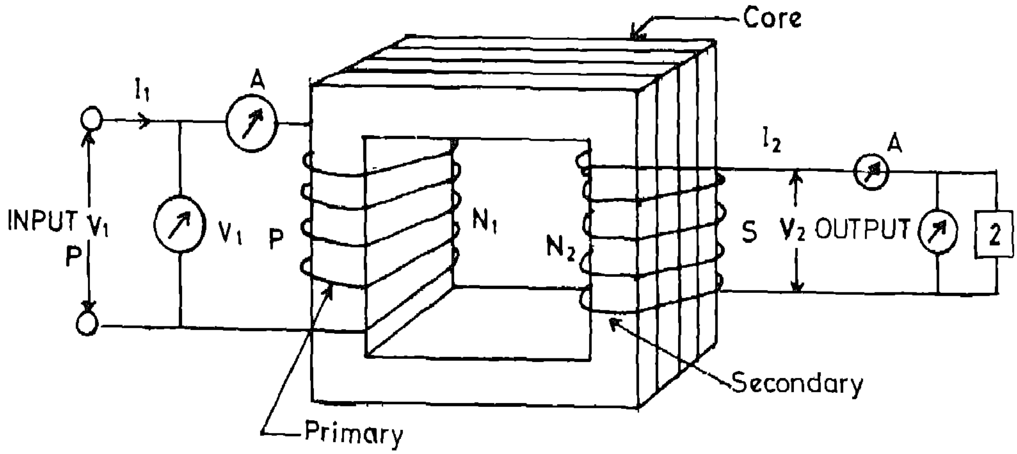


Fig. 29.1

connected is known as primary and the other winding is known as secondary.

When a transformer increases the output voltage it is known as step-up transformer. If it reduces the output voltage it is called as step-down transformer. The ratio of output voltage to input voltage is known as the transformation ratio (K). It is also expressed by the equation :

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K$$

where V_1 = primary voltage
N_1 = primary turns
I_1 = primary current
V_1 = secondary voltage
N_2 = secondary turn
I_2 = secondary current

Transformation ratio (K) is greater than 1 for a step-up transformer whereas, it is less than 1 for a step-down transformer.

Equipment and Materials

(i)	Single-phase transformer	250V/500V 0.5KVA	— one
(ii)	Moving iron voltmeter	0-250V	— one
(iii)	Moving iron voltmeter	0-500V	— one
(iv)	Moving iron ammeter	0-5A	— one
(v)	Moving iron ammeter	0-3A	— one
(vi)	Lamp board	200w bulbs	— 6 nos.

Procedure

(i) Make the connections as shown in Fig. 29.1

(ii) Switch on the lamp load (two bulbs at a turn).

(iii) Switch on the supply and take the readings

(iv) Calculate the transformation ratio.

Observations

S. No	V_2	V_1	$K = \frac{V_2}{V_1}$	I_1	I_2	$K = \frac{I_1}{I_2}$
1						
2						
3						
4						
5						

Result

The transformation ratio is.......... .

Precautions

(i) Instruments of proper ranges should be used.

(ii) The primary of a transformer should never be connected to a D.C. supply.

(iii) Use shades to avoid glare.

Questions

(i) Can you name the various losses occuring in a transformer?

(ii) Why is the core of a transformer made of silicon?

(iii) Why is the core of a transformer laminated?

(iv) What will happen if the primary is connected to D.C.?

(v) Given N_2 = 1000, N_1 = 200, calculate K

ACTIVITY NO. 30

To Determine the Efficiency of a Single-Phase Transformer

Specific Objectives

(i) To be aware of the losses in a transformer.
(ii) To calculate the efficiency of a transformer.

Related Information

This is the direct method for determining the efficiency of a transformer, and is applicable only to small capacity transformers. The reason is that it is not easy to give full load to a large size transformer and if full load is given there will be no wastage of power.

The ratio of output power to the input power of a transformer represented in terms of the percentage is known as the efficieny of a transformer. The input and output of the transformer are measured with the help of two wattmeters at a desired load and the efficieny is calculated as:

$$\text{Efficiency of transformer} = \frac{\text{output}}{\text{input}} \times 100$$

Transformer has static losses namely, copper losses (due to series winding) and core losses (hysteresis and eddy current loss). Alternatively, efficiency of a transformer is also given by

$$\frac{\text{input} - \text{losses}}{\text{input}} \times 100$$

Equipment and Materials

(i)	Ammeter	0-10Amp	— 1
(ii)	Voltmeter	0-115volt	— 1
(iii)	Voltmeter	0-300volt	— 1
(iv)	Ammeter	0-5A	— 1
(v)	Wattmeter	0-350W	— 2
(vi)	Transformer	230/115V	— 1
(vii)	Auto Transformer	1 KVA 15 Amp. 230V	— 1
(viii)	Rheostat		— 1
(ix)	Connecting wire	15A, 230V	— length as required

Procedure

i) A circuit is connected as given in Fig. 30.1.

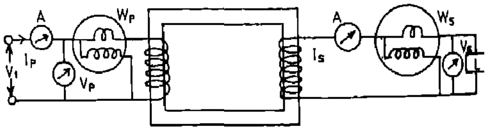


Fig. 30.1

(ii) Rated voltage is applied to the primary side of the transformer with the help of auto-transformer and no- load secondary voltage is measured.

(iii) The transformer is loaded upto its half load and full load, respectively with the help of rheostatic load and the readings are noted.

Observations

S.No	Voltage (V_p)	*Primary* winding current (I_p)	Secondary winding power (P_p)	Voltage (V_s)	Current (I_s)	Power (P_s)
1						
2						
3						

Calculation Efficiency = $\frac{\text{output}}{\text{input}} \times 100$

Precautions

(i) Experiment must be carried out at the rated transformer voltage.

(ii) Readings for input power and output power should be taken out after consideration of wattmeter multiplier.

(iii) Proper range on wattmeter should be selected.

Questions

(i) Why is the efficiency of a transformer higher than the rotating machine?

(ii) Can you name the various losses taking place in a transformer?

(iii) Define efficiency and write its formula.

(iv) If the output of a transformer is 400 watts and the input is 500 watts, calculate its efficiency.

ACTIVITY No. 31

To Measure Current in an A.C. Circuit using Current Transformer and Tong Tester

Specific Objectives

(i) To be familiar with the use of current transformer (C.T.) as a device for range extension of an ammeter.

(ii) To measure current in a live circuit with the help of a tong tester.

Related Information

Current transformer is basically an instrument transformer and is used for range extension of an A.C. ammeter. With the help of this instrument, high current can also be measured by a low range ammeter. Current transformers (C.T) are of two types :

(i) Conventional Type

It has two windings; primary and secondary. The primary is made of thick copper conductor with a less number of turns to carry large currents while the secondary is made of thin copper wire having a large number of turns to carry small currents.

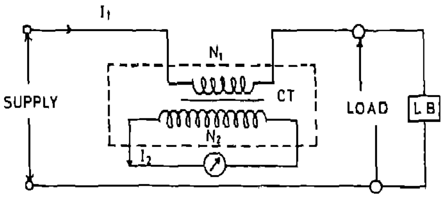


Fig. 31.1 Current transformer

(ii) Ring Type

As the name implies it is in the form of a ring made of a number of copper-wire turns and forms only the secondary of a transformer. It is simply put on high voltage iron conductor, which serves as its primary.

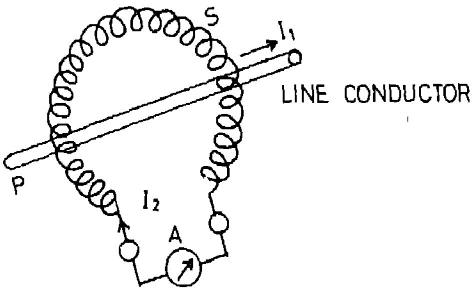


Fig. 31.2

The transformer ratio of a transformer is given by the following equation :

$$\frac{V_2}{V_1}=\frac{N_2}{N_1}=\frac{I_1}{I_2}=K$$

where V_1 = primary voltage
V_2 = secondary voltage
N_1 = primary turns
N_2 = secondary turns
I_1 = primary current
I_2 = secondary current
K = transformation ratio

In the case of C.T., we use only a part of the above formula i.e. $\frac{N_2}{N_1} = \frac{I_1}{I_2} = K$

For example: In a C.T. if $N_1 = 10$, $N_2 = 1000$

If $I_1 = 1000A$, what is the value of I_2?

$$\frac{N_2}{N_1} = \frac{I_1}{I_2}$$

$$\therefore \frac{1000}{10} = \frac{1000}{I_2}$$

$$I_2 = 10A$$

i.e 1000 Amp can be measured by a 0-10 Amp ammeter only with the help of a C.T.

A tong tester is basically a C.T with split-type of core which is arranged in such a way that it can be opened out at a hinged section by merely pressing a trigger-like lever. The opened core permits the entry of high current-carrying feeder or bus-bar within its core, then the core is closed tightly and the feeder begins to act as primary. The secondary winding as core, connected to an ammeter indicates the current. A typical tong tester is illustrated in Fig. 31.3. The circuit for measurement of current with the help of tong tester is given in Fig. 31.3.

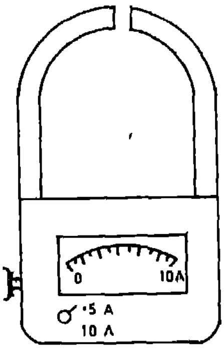


Fig. 31.3

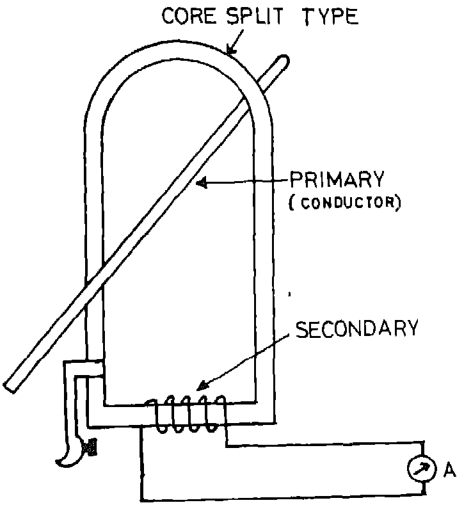


Fig. 31.4 Current measurement with a tong tester

Equipments and Materials

(i)	Current transformer	10:100	— one
(ii)	A.C source	250V, 50Hz	— one
(iii)	Lamp load	200W, 20Nos.	— one
(iv)	Tong tester	5A/10A	— one
(v)	Ammeter	(0-3A)	— one

Procedure

(i) Make the connections as shown in Fig. 31 1.

(ii) Switch on the lamps (10 nos.), fitted in the lamp board and note the ammeter readings. Then switch on the other 10 lamps and note the readings.

(iii) Get the actual current in each case by multiplying by the C.T. ratio.

(iv) Take the same current readings (as in sl. no. ii) by a tong tester and compare with those taken by the current transformer.

(v) Compare the readings observed by the current transformer and tong tester (both will be the same).

Observations

S.No.	*Ammeter reading (A)*	*Actual current A × K*	*Tong Tester reading (A)*	*Remarks*
1				
2				
3				
4				
5				

Precautions

(i) The secondary of a C.T should never be left opened.

(ii) The multiplying ammeter readings by K to get actual current.

Questions

(i) Why is the a C.T. called instrument transformer?

(ii) What is the application of a C.T ?

(iii) Why should the secondary of a C.T. never be left opened?

(iv) What is the advantage of a tong tester for the current measurement over ammeter?

(v) What part of circuit acts as a primary in a ring-type current transformer?

ACTIVITY NO. 32

A Visit to a Hydroelectric Power Station

Specific Objectives

- (i) To visit dam site/Forebay tank/ water reservoir/canal, etc.
- (ii) To study the operation of a turbine.
- (iii) To study the operation of a generator unit.
- (iv) To study the cable connections from generator to power transformer.
- (v) To study the electrical equipments in the outdoor switch-yard and the connection to transmission/ distribution line.

Related Information

An electric generator converts mechanical energy into electric energy. The mechanical energy (for driving or rotating the generator) is supplied to the generator by a primeover such as steam turbine, hydraulic turbine, etc. Steam turbines are used in thermal power stations whereas hydraulic turbines are used in hydroelectric power stations. When the water strikes the blades of a water turbine, the turbine rotates. As the generator is mechanically attached with the turbine, it also rotates along with the turbine. The amount of electric power generated by the generator depends upon the quantity of water available and the water-head.

The generator unit is made up of two parts namely, the stator and the rotor. The exciting coils and the field poles of the generator are situated on the rotor which rotates along with the turbine. The stator part does not rotate. Electric power output is obtained from the stator (winding) part of the generator.

The field coils (situated on the rotor) are connected to the exciter through slip rings. The exciter is a DC generator mounted on the same shaft on which the turbine and the generator rotor are mounted.

Connections from the generator are brought out to the primary windings of a power transformer by means of a three-core cable. Usually terminal-voltage of a generator is 11KV, whereas the transmission voltage may be of the order of 66 KV, 132 KV, 220 KV, 400 KV, etc. Hence, a step-up power transformer is used at the power station site.

From the transformer secondary (high-voltage side) the connections to the overhead lines are made through isolators and circuit breakers. An isolator is a switch which is operated when the load is off. A circuit breaker is an automatcally controlled switch which operates on load or even on a fault.

The student is advised to draw a detailed layout diagram of the power station that he has visited.

Procedure

Visit the following sections of the powerhouse and take note of the various equipments that you come across:

(i) Dam site/Canal headworks/water reservoir/Forebay tank. Watch the control of water flow from the main source of water to the penstock.

(ii) Penstock installation

(iii) Power house :

- sluice gate
- hydraulic turbine (inlet/outlet)
- tail race
- bearings
- generator unit
- specifications of the generator unit
- number of generating units
- exciter
- control room
- governer control
- overhead crane
- cable connections outgoing from the generator

(iv) Outdoor switch yard

- cable trenches
- circuit breakers
- power transformer (primary, secondary and buchholz's relay)
- lightning arrestors
- current transformer
- potential transformer
- grounding mat
- isolator.

Transmission Line

- line insulators
- line conductors
- power line carrier communicated equipment
- transmission tower
- vibration dampers on transmission lines

Observations

(i) Specifications of the generator unit

- M.V.A. rating
- voltage rating
- current rating
- speed of rotation
- frequency

(ii) Specifications of the power transformer

- primary voltage
- secondary voltage
- KVA or MVA rating

(iii) Number of generator units

(iv) Number of feeders going out from the power station

(v) Peak-load of the power station

(vi) Head of water at the power station

(vii) Rate of water flow in the penstock pipeline

(viii) Diameter of the penstock pipe

(ix) Transmission voltage

(x) Material of the transmission-line conductor

(xi) Number of strands in the transmission-line conductor

(xii) Distance of transmission

(xiii) Type of insulator used on the transmission line

(xiv) Number of discs in the insulator string.

Precautions

(i) Do not touch any equipment in the power station.

(ii) Do not crowd up around any equipment in operation in the power house

(iii) Do not move around the power

station without the company of a technical expert from the power house.

Questions

(i) Is the speed of a generator constant?
(ii) Is the shaft of a generator set vertical or horizontal?
(iii) How is the voltage induced in the starter winding?
(iv) What is the importance of a power transformer?
(v) Does the power generated by an alternator remain constant during 24 hours a day?
(vi) Are the various generator units in a power house interconnected electrically?
(vii) How does the electrical power generated in a power station reach various consumers of electrical power?
(viii) What is the frequency of a power supply?
(ix) Does the generator generates A.C voltage or D.C. voltage?
(x) Draw a general lay-out of the power station that you have visited.
(xi) Draw an electrical lay-out of the power station that you have visited.

ACTIVITY NO. 33

A Visit to a Thermal Power Station

Specific Objectives

(i) To become familiar with a thermal power station.
(ii) To understand the basic schematic layout of a thermal power station.
(iii) To understand the functions of the basic equipments of a thermal power station.

Related Information

In a thermal power station, the heat energy obtained by the burning coal is utilised to convert water into steam. In a boiler the steam is passed through a steam turbine which converts heat energy into mechanical energy. The turbine acts as a prime-mover for the alternator. The turbine supplies mechanical energy to the alternator. The alternator converts mechanical energy into electrical energy.

A thermal power station requires ample quantities of water and coal. While selecting the site, these factors are kept in mind.

Procedure

(i) Follow strictly the instructions given by the guide regarding safety measures.
(ii) Start your visit from the coal handling plant.
(iii) Listen carefully to the information given by the guide.
(iv) Observations should be noted in the power station itself.
(v) Observe and note the following:

A. *Coal and ash handling plant*

type of coal-handling arrangement
quantity of coal used per month
is the coal pulverised?
type of ash-handling arrangement
disposal arrangement for ash.

B. *Air and gas circuit*

method of air heating
type of draft
basic function of a chimney.

C. *Feed-water and steam circuit*

source of raw water
reason for water treatment
basic function of a boiler
type of boiler
pressure of outgoing steam
temperature of outgoing steam
basic function of a turbine
type of turbine
speed of turbine
pressure of the output steam in the turbine
basic function of a condenser

D. *Alternator (AC generator)-exciter*

MVA/KVA output of the alternator
generation voltage
frequency
speed
number of poles
type of alternator
type of excitation system
excitation voltage

E. *Control room*

name the various types of relays used:
(i)
(ii)
(iii)
measuring instruments :

S.No	*Name of the meter*	*Basic function*	*Reading at the time of the visit*
1	Ammeter		
2	Voltmeter		
3	Frequency meter		
4	Power-factor meter		
5	Energy meter		
6			
7			

F. *Transformer*

KVA/MVA rating
input voltage/output voltage
winding connection primary/secondary
method of cooling
physical dimensions
basic functions of:
(a) transformer
(b) conservator
(c) breather
(d) buchholz's relay
(e) transformer bushing

Precautions

(i) Do not touch any equipment without permission.
(ii) Maintain a safe distance from all the equipments.
(iii) Do not disturb the normal working of the power station.
(iv) Observe strictly the safety instructions.
(v) Move along with your guide.

Questions

(i) An alternative converts_____ energy into _____ energy.
(ii) Why is coal pulverised?
(iii) Name the five main auxiliaries of a thermal power station.
(iv) Mention the total installed capacity of the power station visited.
(v) Is the alternator excitation AC or DC? Why is it so?
(vi) What is the function of a cooling tower/cooling fountain?
(vii) A thermal power station causes atmospheric pollution. Explain.
(viii) Mention the location of the following:
  (a) instrument transformers
  (b) circuit breakers
  (c) relays

ACTIVITY NO. 34

A Visit to a Substation

Specific Objectives

(i) To study in detail the layout and the performance of the equipments in the yard.
(ii) To observe the basic equipments and meters in the control room including the battery room.
(iii) To understand the basic duties of a lineman in a substation.

Related Information

A substation is a very important part of the entire power system It is a link between the transmission and the distribution systems. It needs regular maintenance and quick repair in case of a fault. A lineman has a very important role in the substation, particularly in the yard A modern substation is very complex in nature. It has various types of equipments for the transmission, distribution, protection and control of electrical power. All these are inter-connected in the substation. Since the voltage level is very high it is very important to take all the precautions while working in the yard. The lineman must observe the necessary safety precautions under all circumstances

Substations are of three types .

(a) Pole-mounted substation
(b) Substation
(c) Grid substation (Gss)

A blueprint of the substation (under study) should be provided to the students.

Procedure

(i) Identify the various types of equipments installed in the substation as per its blueprint.
(ii) Prepare tabular records of your observations.
(iii) Follow the same procedure regarding the blueprint equipments in a grid substation.

Observations at a Substation

(i) *Incoming lines*
voltage
number of conductors
type of conductors
earth wire location
(ii) *Tower for incoming lines*
sketch of the tower
height
type of conductors and insulators
(iii) *Insulators*
type
number per line
sketch
(iv) *Isolator*
location
number
operation
(v) *Circuit breaker*
type

rating
location
sketch the outer appearance

(vi) *Current transformer (C.T.)*
function
rating

(vii) *Potential transformer (P.T)*
function
rating

(viii) *Busbar (H.V.)*
layout
function

(ix) *Lightning arrester*
function
loaction

(x) *Transformer*
voltage
rating
cooling
bushings
sketch of the outer appearance

(xi) *Capacitor bank*
function
rating
position

(xii) *Power-line-carrier commmunication* (PLCC)
basic function
location

(xiii) *Cable (L.V. side)*
function
type
shape/cross-section
joints-type

(xiv) *Feeders*
voltage
number
location

(xv) *Control room*
To take readings of the various meters at the time of visit. Indicate proper units .
ammeter
voltmeter
wattmeter
energy meter
relays:

S.No.	*Name*	*Basic functions*
i)		
ii)		
iii)		

(xvi) *Battery room*
types of batteries
total number of batteries
working voltage
function

(xvii) *Protection against fire*
types of fire-fighting equipments
location
maintenance

(xviii) *Duties of a lineman in a substation*
(a)
(b)
(c)

Precautions

(i) Follow strictly the instructions given by the guide while visiting a substation

(ii) Do not touch any equipment.

Questions

(i) Why do lines (input-output) have different voltage levels?

(ii) Explain how 3-line conductors and the earth wire are arranged in a H.V line.

(iii) What is the basic function of an earth wire?

(iv) Is there any relationship between the height of the tower and the operating voltage?

(v) Explain the relationship between the number of discs in an insulator and the operating voltage.

(vi) Explain clearly the functions of an isolator and a circuit breaker

(vii) Explain the sequence of operation of an isolator and circuit-breaker while · (a) making (b) breaking.

(viii) Explain the functions of
  (a) (C T.) Current Transformer
  (b) (P.T.) Power Transformer

(ix) Discuss the functions of a busbar

(x) Explain the functions of a lightening arrester.

(xi) What are the duties of a lineman in various types of substations?

(xii) Explain the functions of the following in a transformer .
  (a) Buchholz's relay
  (b) conservator tank
  (c) breather

(xiii) Which equipment is responsible for the improvement of the power-factor?

(xiv) Why is a cable used in the substation?

(xv) Explain the role of a feeder in a distribution system.

ACTIVITY NO. 35

A Visit to an Industry

Specific Objectives

(i) To exposes the students to an industrial environment.
(ii) To observe the electrical installations (wiring, electrical motors, other electrical equipments).

Related Information

Every industry has two types of loads :
(i) Power load
(ii) Lighting load.

A fairly big industry has an outdoor/indoor substation. Every industry uses a large number of electrical motors for various purposes.

The teacher accompanying the pupils is required to explain about the electrical wiring of installation and process-flow diagram.

Procedure

(i) Follow strictly the safety precautions being observed in various sections.
(ii) Do not touch any equipment without permission.
(iii) Pick up the relevant information systematically.

Observations

(A) *Substation*
incoming voltage/outgoing voltage
bating
types of cooling of transformer
protection system
single-line diagram
details of panel board
methods of p.f. improvements.

(B) *Electical installation*
number of distributing circuits
types of wire used and their current rating.

(C) *Motors*

S No	*Type of motor*	*Horse power*	*Type of starter*	*Method of speed control, if any*	*Applications*
1					
2					
3					

(D) *Other electrical equipments*

S No	*Type of the equipment*	*Rating application*
1		
2		
3		

name of the product
basic raw material used
names of different processes :

S.No	Name of the process	Input	Output
1			
2			
3			

Precautions

(i) Visit the factory wearing proper clothes.
(ii) Do not disturb the normal working of the factory.
(iii) Follow strictly the safety precautions being observed in various sections.

Questions

(i) Explain service mains.
(ii) Name the types of the motors used.
(iii) Have you seen any D.C. motor?
(iv) Which type of speed control have you seen?
(v) Explain the methods of protection of the individual motor.
(vi) How may workers are there in the factory?
(vii) Comment on the hygienic conditions in the factory.
(viii) What types of fire-fighting equipments are used in the factory?
(ix) Have you observed the first-aid chart for an electric shock?

Appendix

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